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ABSTRACT

Characteristics of liberal arts education and different approaches to educational modeling are examined. Attention is directed to: applications of graphic depictions; Venn-Euler diagrams to represent inclusion-exclusion phenomena as well as areas of commonality in learning processes and liberal education; the uses of flow charts for describing contrasting models for integrative learning; pattern recognition techniques providing an empirical methodology for the identification of elemental components to be incorporated into a general system for liberal learning; a variety of vectorial models for projecting influences that determine the structure of liberal arts curricula; and rudimentary concepts drawn from matrix theory that provide useful ways for a restructuring at a fundamental level of the elements of generalization in the curriculum. It is suggested that liberal learning requires modes of action and changes of behavior in which there is some evidence of continuity and direction within that total process. The emergent patterns involve larger goals than the mastery of specific disciplines and the enhancement of particular skills. A case study of the requirements for the B.A. degree and appended materials on pattern recognition and symbolism in flow charts are included. (SW)

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PATTERNS IN LIBERAL ARTS CURRICULA

A Survey of Program Models

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PREFACE

There are a number of ways to initiate the revision and development of undergraduate curricula so that liberal learning may be fostered. The least difficult aspect of such activities is the formulation of a statement of purposes and educational objectives for the given curriculum in which sets of general goals for liberal education are identified. However, the translation of those objectives into specific requirements and particular course contents presents obstacles which are not easily overcome; and at this stage there are always the practical options available, namely, to first seek a helmsman to resolve the strategic issues related to program formulation and adoption and, secondly, to import an existing program from outside the institution or to revive a traditional program formerly used at the same college. Thus, it is not surprising that faculty responses to curriculum development are often less than enthusiastic and frequently are characterized by muddled thinking. In order to appraise particular features of a new set of requirements for liberal arts degrees as well as the outcomes of such programs, one must recognize that both strategic and substantive factors shape the curriculum.

As we attempt to make a more objective examination of educational program development problems at the college level, unique questions are directly encountered which are associated with any deliberate institutional choice to bond together an extremely diverse set of subject field elements into a seemingly coherent whole. Planning procedures used at the primary and secondary levels of education can be unified around thematic goals projecting personality theories and methods of inquiry. However, undergraduate education is bounded strongly by the disciplines, and, by tradition, it has been more subject-oriented than person-oriented. Thus, in curriculum planning for the college years it has become increasingly difficult to identify and cultivate coherent educational philosophies even within the single assembly of the liberal arts.

As important as financial considerations are at the present time, a critical issue for the liberal arts college is that of developing its program goals and program organization. Our tools for review of both our objectives and our practices derived from these are not adequate for our tasks, nor have most of us as faculty members done enough homework to understand the present conditions within the context of the recent history of higher education.

This monograph is an outgrowth of my attempts to distinguish between the new and merely imitative programs for liberal learning and to address the often confused and conflicting claims made by advocates of particular statements of general requirements. The study evolved from one solidly empirical conclusion: namely, diagrammatic models and a more precise language are required for any effective analytical treatment of undergraduate curricula. Of course, all such models are simplifications seeking to identify essential components within multivariant systems with the intent that clarification will accompany approximation. It was not my goal to find <u>the model</u> for liberal education nor to provide a comprehensive review of approaches to the construction of models in the field of education. Rather, several different models have been examined in terms of their potential for explanation and prediction, and only those techniques for modelling which appear to be most applicable to the description of curricula and learning processes in higher education are included. Several mathematically based constructs are incorporated into these models; however, a special effort has been made to avoid a pre-occupation with the mathematical

symbolism and manipulations at the expense of fundamental educational concepts. For this reason, the level of mathematical skills employed has been purposely restricted to those derived from college algebra or finite mathematics as the assumed common background for most readers.

The complex of educational philosophy and practice seems to give evidence for the interplay of many forces intersecting in a variety of ways and each with a differing impact upon the structure of the total curriculum. In order to represent the relationships among these forces the mathematical concept of the vector and vectorial interactions has been utilized for much of the interpretive analysis given in this monograph. However, alternative models for organization are surveyed in general terms as well as detailing the structural features which may be derived from vector models. Thus, simplified flowcharts and Venn diagrams have been incorporated where these are adaptable to the visual descriptions of learning and teaching processes. The greater use of visual diagrams in the more recent "handbook" type of publications dealing with curricular and management systems in higher education encourages some of us to believe that our methods for program development may yet become less crude and more nearly adequate for the tasks at hand.

This volume is an expanded and revised form of an earlier monograph which was published in 1976 by Xerox University Microfilms, Ann Arbor, Michigan. Several more recent external factors supplied the impetus for preparing the present revision, including the extensive published studies concerning current needs for liberal education and supported by the Carnegie Foundation for the Advancement of Teaching and the Council for the Advancement of Small Colleges, as well as the much publicized Harvard Report of 1978. Likewise, within the renewed interest in curriculum revision among many colleges, there is the temptation to simply re-arrange former ideas or indeed to revive old programs for liberal education which were abandoned decades ago. Liberal learning need not be specified only by retrograde programs of general requirements; however, without better tools for the critical examination of our curricula the risk of such an outcome is very real.

Many readers will quickly recognize my great indebtedness to those primary investigators who are working in the broad area of model construction and who are cited in the bibliography. Also, I freely acknowledge the serious efforts of those persons within and beyond the institution whose thoughtful comments on the earlier version of this work have forced me to re-think and extend some of the modelling techniques applied previously.

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Chapter I

INTRODUCTION TO MODELS

Programs and propositions for collegiate level liberal education confront the immediate fact that there are clear limitations on the dimensions within which any structure can be assembled, namely time and the boundless extension of knowledge. Yet liberal learning requires much more than merely being responsive to information, its movement, discovery, storage, and retrieval. These are peripheral to the more fundamental processes of thought, awareness, and correlation, as cofactors in the ordering of educational experiences for continuity and intelligibility. Therefore, the courses and their combined curricula are symbolic analogs for the more basic processes and underlying goals.

Susanne Langer's two-fold classification of knowledge symbols is particularly pertinent to any review of liberal education.[1] The first category, the discursive symbols, indicates direct correspondence between objects and names or concepts, and becomes the fact or law elements of verifiable knowledge. The second, non-discursive symbols, includes virtual experience or the intuitive cognition of form and synthesis, and these evolve to the creative perception of relatedness or design. Contrasting time senses exist in each: the first implies the clock time regularity and continuity for time as a mathematical variable; and in non-discursive symbols "time exists for us because we undergo tensions and their resolution".[2] Thus, the programs for liberal learning, however elaborate in form, must relate the interactions of the discursive and non-discursive elements in all knowledge discovery at all chronological levels.

The human dialogue between discursive and non-discursive language symbols invents new terms and creates new meanings from old knowledge data, a process which must be mobilized in liberal education. Although this interaction and synthesis can surface in a great range of subject fields, it is not necessarily a spontaneous or inevitable event. Too often the course emphasis in undergraduate education follows a time and fact sequence with generalizations restricted to their specific interrelationships. The premise of liberal education is that suitable conditions can be devised in which a more comprehensive symbolic interplay is more likely to occur.

Characteristrics of Liberal Arts Education

It is appropriate to consider a working definition of the liberal arts curriculum as we begin this discussion of different approaches to educational modelling. By tradition the term, curriculum, has been considered to represent an ordered teaching pattern of subject matter courses positioned in an overall time frame which is determined by the particular academic degree. However, since instructional programs are no longer limited to the lecture or formal classroom style, a more flexible and complete definition is needed.

For our purposes, the liberal arts curriculum can be defined tentatively as a designed program of both broad and varied learning experiences, using student-teaching interactions to optimize the development of mental processes and to cause attitude changes on the part of the student. Thus, the curriculum becomes a total system for the management of learning and encompasses both

process and content elements.

When described in this way, a curriculum for liberal learning is freed from a commitment to specific subject matter in order to focus upon those skills, abilities, and attitudes common to learning in many subject fields. William Stuyner has stated three goals for individual growth within such a curriculum:[3]

(a) cognitive capabilities - including organizational and communicative skills;
(b) affective applications to new and changing problems;
(c) other-directed development - by relating to the various communities of which the individual is a part.

The first two categories (cognitive and affective) are patterns of action derived from the widely used scheme of B. S. Bloom for identifying human learning capacities. The Bloom "taxonomy" includes within the affective domain receiving-responding functions of the brain as well as preferences, values and feelings or emotions expressed toward that which is being observed and learned. By contrast, the cognitive domain encompasses the totality of the rationalistic learning capabilities from simple factual material received to its organization, analysis, and the development of synthetic interrelationships.

Some of the relationships implied by the above definition can be visualized through the diagram in Figure 1-1. In somewhat traditional programs for liberal learning the inputs originating with the teacher are the more easily manipulated variables which are used to initiate behavior changes on the part of the student. The overall model for the process is usually a linear one in which the immediate as well as the longer term outcomes of given program are evaluated by periodic testing of students. Thus, the visible evidences for the outcomes of the learning mechanisms require both record-keeping (a time function) and evaluation (a content-experience function); and the usual emphasis for the latter is upon testing for the easily verifiable components of factual knowledge and/or particular skills. In this respect evaluation methods for liberal education largely mimic those of the disciplines even though the objectives and the dominant learning mechanisms may be substantially different.

Although the suggested definition includes altered attitudes and behavior as a part of the output of liberal learning, it is not confined by any single theory concerning the nature of mental processes nor does it imply a particular methodology for learning. Of course, the behaviorist view with its emphasis upon observable behavior and operational empiricism has been effective in initiating sequential learning of basic skills and in measurably altering human behavior. However, the complexity of individual mental growth requires a broader range of learning strategies appropriate to the tasks undertaken at the college level. In several respects the foregoing definition of the liberal arts curriculum is closer to the outlook of cognitive psychology than to behaviorism, for the former examines the mind as a coherent system performing a variety of interrelated functions and responding selectively to the stimuli in a given information or knowledge environment. It is clear that action is the normal condition for the human mind and that almost an infinite number of external stimuli modify, transform and redirect our patterns of action.

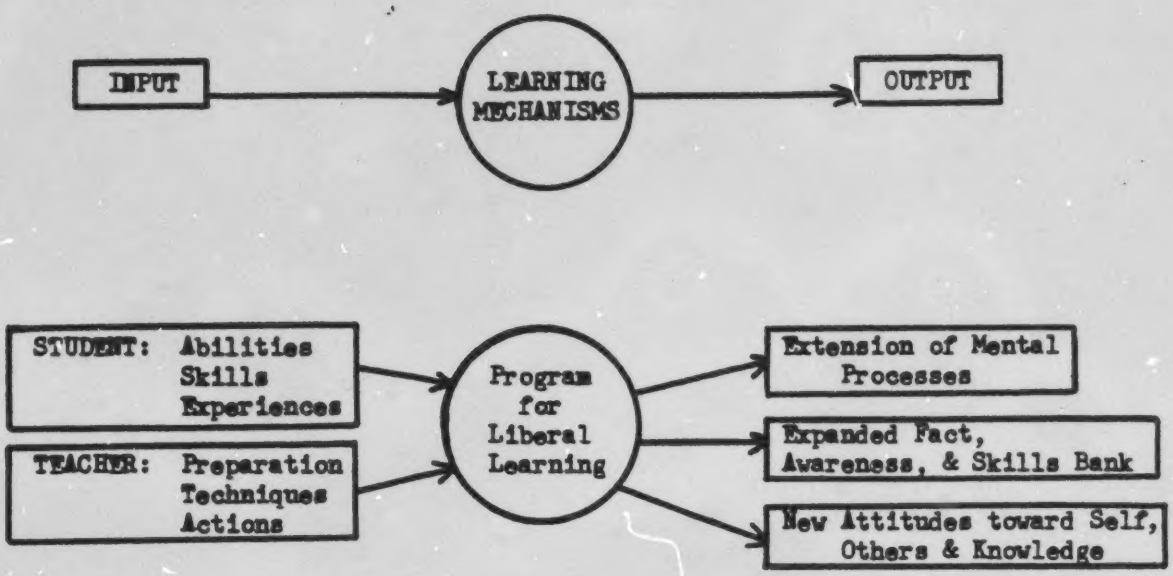


Figure 1-1. An input-output view of liberal education

Thus, any realistic definition of liberal learning must focus upon action as a fundamental dimension in all learning as well as specify anticipated goals or outcomes for that process in which a new reality is to be continuously created. Creative acts undertaken by the individual always include processes of selection, organization, and synthesis, although the psychological explanation of such processes may be far from complete or sufficient.

In the course of many years of educational happenings an individual becomes equipped to initiate a range of actions even though limited to a small fraction of these when carried out either simultaneously or sequentially. Thus, out of the store of possible or potential acts, selective responses are forced upon both the learner and upon the curriculum planner as a program for integrative learning is formulated. Clearly, the learning environment in the college years can be characterized by diversity, not only in subject matter and areas of specialization but also in the realms of the teleological and epistemological assumptions made about the total enterprise of learning itself.

Attitudinal orientations on the part of the student must be confronted directly within any setting for liberal learning since all of us repond to writing and visual sources of information from a vantage of our own longstanding prejudgments derived from our past linguistic experiences and our cultural-literary tradition. In our attempts to stimulate students to allow the new or present sources to speak independently of these personalized conditioning perspectives, a temporary withholding of judgement on the part of the student is necessary. For there to be reflection upon the meaning of that which is being read or observed and for there to be interpretation of the information as a prequisite to understanding, a change of attitude toward the unfamiliar or the new is essential and the teacher assumes a facilitating role in that redirection.

Knowledge structure and organization can be abstract and static and yet have current validity. However, it is the dynamics of a given field, the key questions in that field, and the means for continuing inquiry which constitute the dimension of significance for education as a process. In fact that process can never operate in the absence of a knowledge-data base. This totality of knowledge impact requires simplification by grouping, and the following categories are fairly self-evident.

(A) Bodies of facts and their descriptive relationships.

(B) Symbolic methods for thinking, learning, communicating, and self-expression.

(C) Paths of human cultural development.

(D) Value schema and beliefs.

(E) Analysis and regulation of the social order.

Classifications of this type do not coincide with our catalog of the disciplines and yet it is from the stuff of particular subject fields that curricular organization is built. Obviously, programs designed for the preparation of specialists in the various fields should differ form those intended

to educate the non-specialist. The first tries to approach the professional standards of performance, but the second too often may be provided only a superficial historical survey of what has been done in the particular field of study.

Interdisciplinary courses have been designed to serve the breadth dimension and to overcome the limitations of surveys; however, because of the varied use of this term, some restriction of its meaning is necessary. A workable definition given by Elbow is that interdisciplinary studies begin with subordinate concepts drawn directly from the disciplines themselves, and these are brought together with the purpose of seeking some new relationships among them.[4]

Although more concerned with the internal structure of the disciplines, the ideas of Bruner relate directly to the larger organizational problem of the curriculum to include interdisciplinary learning. "Human beings....have developed three parallel systems for processing information and for representing it -- one through manipulation and action, one through perceptual organization, and one through symbolic apparatus. It is not that these are stages in any sense; they are rather emphases in development."[5] From the viewpoint of Bruner, structure assumes an operational definition in that it is a tentative reference framework from which the larger body of knowledge can be re-generated. "The merit of a structure depends upon its power for simplifying information, for generating new propositions, and for increasing the manipulability of a body of knowledge."[6] It follows then that structure in liberal arts education should evolve a new coherence and synthesis of knowledge, and it is not exclusively a sequential pattern adapted to efficient knowledge organization alone. The educational and intellectual activities embodied in liberal education are directed as much toward a re-construction of that which is known within the individual human mind as toward the reorientation of specific conditions for learning within a framework of particular external goals. In order for this to occur it is clear that more than a breadth of knowledge and a range of experiences is required; and, therefore, the breadth dimension in liberal education is but one essential part of the total learning field of the student.

Institutional educational goals are not necessarily synonymous with curricular objectives; however, the Delphi method has considerable potential in relation to overall program planning for the college. For this purpose, Winstead and Hobson draw a distinction between goal statements and learning objectives, noting that the first is an idealized focus or direction while the latter can be purely an operational translation of the goal statements into tasks which can be measured.[7] As a research technique, the Delphi method is directed toward a goal convergence if not a full consensus. From a planning point of view, it requires item data acquisition, evaluation of assumptions, formulation of a plan, and the vital ingredient of broad-based feedback to yield program modification. The Delphi method does not necessarily extend beyond a given existing plan, although greater unity of goals and mechanism for change can evolve. Some comparable procedure is sound practice for the establishment of the pre-requisite goal foci.

A variety of formats have been used and recommended for liberal arts programs, and these reflect the varied educational goals of the authors. Most contemporary models begin with a concept of "general education" having the function of providing a common core of learning, a counter force to knowledge

fragmentation, and an understanding of Western or World Culture. Overall planning involves the permutation of the interdependent variables of objectives, integration between fields, and evaluation of the result, with the intention that the structure will contain an identifiable centroid which is "general". In this respect curriculum planning is fundamentally pragmatic and in the educational tradition of Dewey and Whitehead. However, there is growing disenchantment with general education in its traditional forms, as noted by Ikenberry.[8] "In very large part, the difficulties of general education have come from its sometimes valiant attempts to swim upstream against the major currents of society and against the dominant forces in American colleges and universities."

An excellent summary of recommended specifications used in the organization of the curriculum has been provided by Dressel.[9] His emphasis is practical, but in terms of educational philosophy the distinction between specialized and generalized education is de-emphasized and a reduction of the extent of field narrowness in the undergraduate program is considered appropriate. The breadth dimension is inserted through cross-disciplinary contacts, a practice having a long history in American higher education; and the credit distribution in the extra-departmental areas, including general core courses, occupies 45 to 50% of the total.

In many instances the composition of the general education segment has been matched to the certification requirements for public school teachers. Chapman has proposed a series of eleven key questions as guidelines for re-evaluating the organizational emphasis of general educational curricula toward more valid institutional goals.[10]

Curriculum Analysis With Venn Diagrams

From the point of view of liberal learning, a serious disadvantage of the practical approach to curriculum planning is that the basic determinant remains the departmental or divisional group. Thus, the structure of the learning process is made to conform to a design frame which is primarily an administrative convenience. The initial steps in the re-structuring for general education in the historically important Chicago and Columbia reforms (to be reviewed later) had to resolve this conflict.

A second limitation of pragmatic curriculum planning of recent years is inherent in the procedures used to analyze and modify programs. In nearly all cases the methodology relies upon a series of word statements to establish both goals and their derivative structures, and direct logical arguments are employed to connect the two. As the increasing complexity of such a multivariant system becomes known, it is far more difficult to arrive at an adequate correspondence between educational philosophy and educational practice. Likewise, verbal analysis alone does not allow us to clearly distinguish between the truly novel and the merely re-arranged among the many alternate proposals for liberal education.

In attempting to derive a method whereby essential relationships can be identified and logical consequences established, a number of potential options are available; however, all require a more sophisticated language and resultant semantic reduction. A transformation from verbal to logical or mathematical symbols cannot be avoided, nor need it be postponed. The sym-

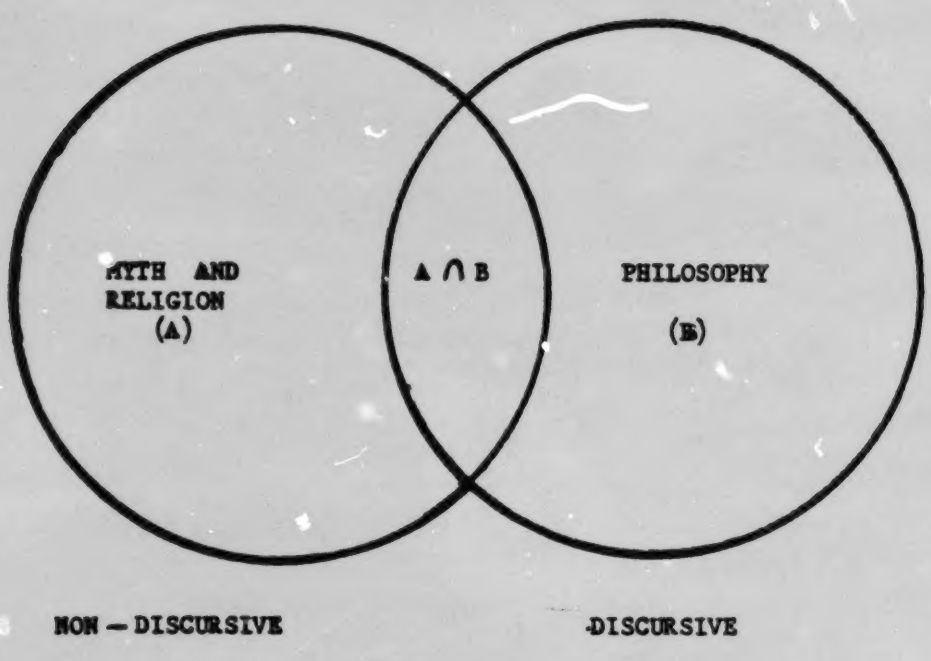
bolic model permits condensation to a minimal set of interacting variables, even though sharing the limitation of all physical models, namely that of being an approximate representation of reality. An asset of the symbolic models is their predictive role, an image often obscured in verbal statements alone.

The theory of sets provides one method for introducing precision into definitions and proofs which may be lacking in purely verbal forms, and the representational construct of the Venn diagram depicts inclusion-exclusion phenomena in a two-dimensional form. For example, in the learning theory of Langer the interplay of discursive and non-discursive symbols between paired knowledge fields can be simply diagramed as in Figure 1-2. The areas of uniqueness and mutual exclusion are clear, and, likewise, the region of intersection combines those characteristics held in common. An additional feature of the intersection is that the order of its formation is unimportant. Also, the view of Langer concerning space-time-energy interactions can be represented by the three-fold Venn diagram of Figure 1-3. The single area of intersection of all three circles depicts the total synthesis of space-time-energy in the visual arts, and yet the two-fold intersections demonstrate relationships involving the two element illusions, as well.[11]

Of course, the planar Venn diagram can be extended to more than three variables; however, the distributive relationships are sufficiently cumbersome that the usual practice is to restrict the sets to three. A simple two-fold case for liberal arts education is given in Figure 1-4, and a three-fold system for scientific knowledge is shown in Figure 1-5. From the point of view of educational planning, both representations underscore the commutative laws for unions and intersections of the particular sets.

The diagram of liberal learning in Figure 1-4 can be related to the earlier operational definition of the liberal arts curriculum. In structuring the set of learning experiences for liberal learning most would agree that more than information items, terminology, and knowledge selection for comprehension are required as the atomistic units in the total assembly. These are the ingredients characterizing disciplinary specialization. On the other hand, generalization involves comparisons in which similarities and differences are lifted up, where trends and correlations among variables are sought or identified, and may evolve model formulations for greater understanding. Generalization and specialization are not fully isolatable functions in any educational process giving rise to real learning, but their dependent interplay unites the affective and cognitive domains in manipulating the specific situation in the context of the general. The re-structuring of human experiences for the enrichment of liberal learning requires the inclusion of the dimensions of both generalization and specialization. However, the intersection of the two in Figure 1-4 implies unique and identifiable characteristics for the region of the intersection iteself. The Venn diagram indicates that this union can be approached initially from either the direction of specialization or from generalization without altering the outcome. The properties of the final union of the two sets remain dependent upon both contributing parts, and, therefore, are more comprehensive than either function alone.

In addition to the limitation on the number of sets of functions which can be adequately handled, the fundamental concept of education as process cannot be easily incorporated into Venn diagrams. The idea of development or progres-



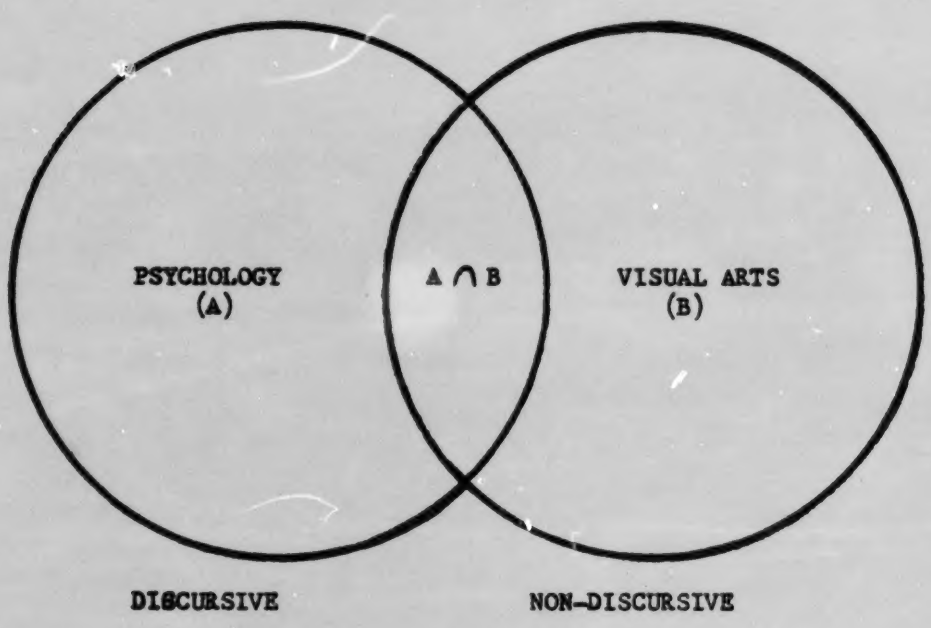


Figure 1-2. Venn diagrams

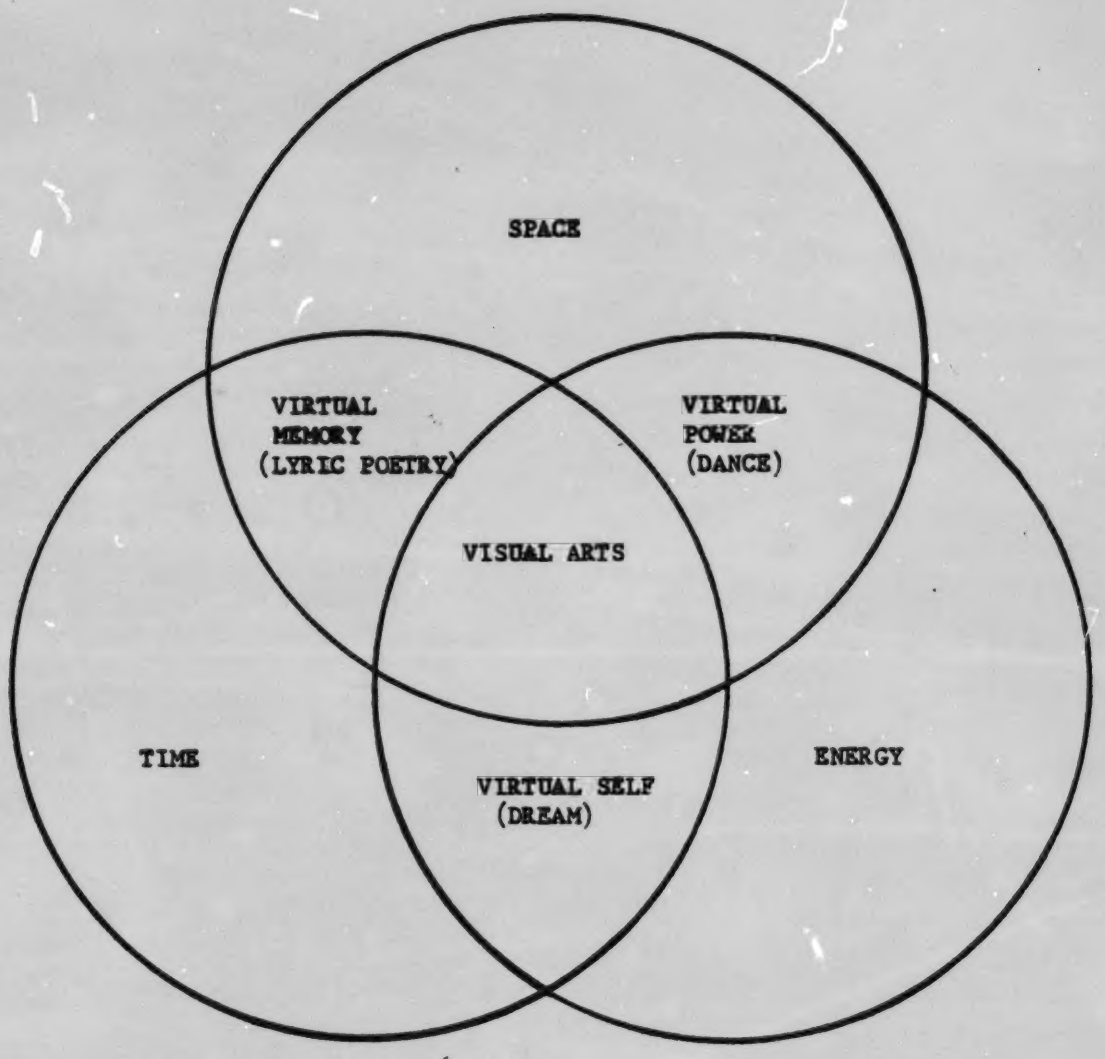


Figure 1-3. Venn diagram for Langer's theory

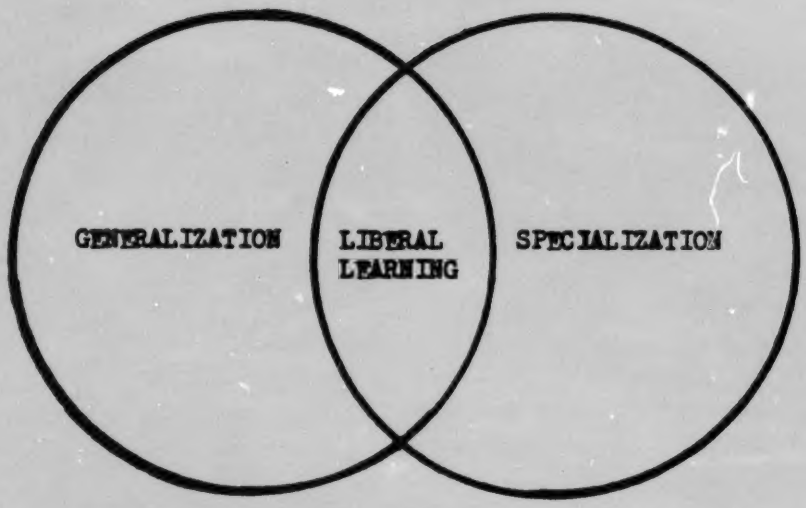


Figure 1-4. Venn diagram for liberal education

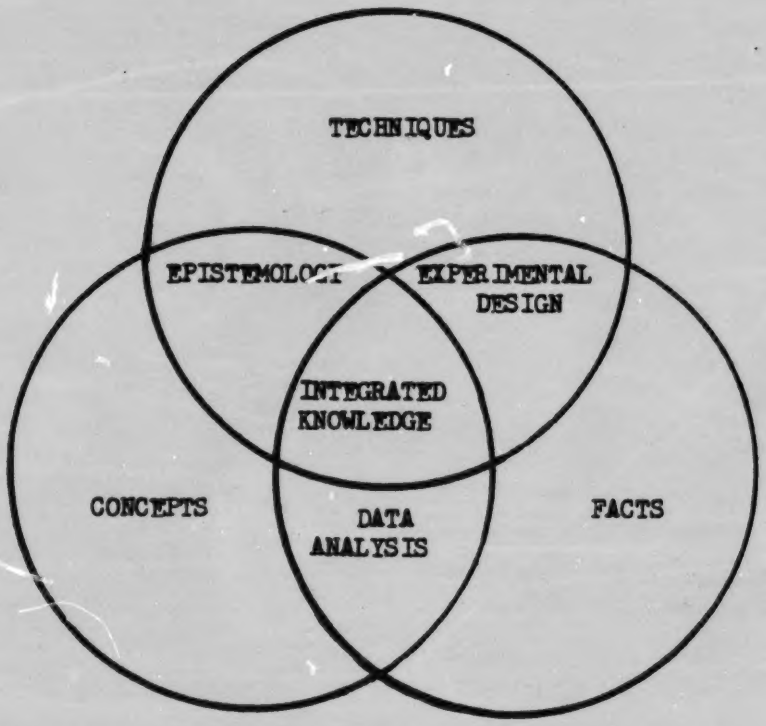


Figure 1-5. Venn diagram for scientific knowledge

sion does not allow an equivalent substitution by a simple time function. The educational progression requires an orderly sequence of learning experiences often based upon connective pre-requisites. Although both discursive and non-discursive elements contribute to the infinitesimal steps to knowing, the result at any point in time is cumulative. Therefore, the measured elapsed time is too incomplete as a scalar quantity to be representational of the flow or movement in educational programs.

The linear presentations of connective relationships used in symbolic logic permit the convenient description of a larger number of elements than is possible with the Venn diagram. Also, the Lewin topological structures can be adapted to the motivational-environmental mix in education.[12] However, both approaches share the underlying deficiency of the Venn diagram: the educacational concept of progression cannot be treated at the level of its importance.

Models In Cartesian Space

Education as process is an essential consideration in any attempt to apply analytical techniques to the structuring of liberal arts curricula. Within any structured learning environment the primary flux for real learning is at least a two-fold mix, as suggested by Elbow: (a) already known concepts are applied by the learner to the widest possible range of situations to which the concepts relate; and (b) methods and data evolve which enable the construction of new concepts.[13] New experiences are in part assembled from the mind's conceptual symbols retained from past learning, coupled with the uniqueness of the new situation. Just as the physical and social growth of the person are ongoing and evolving as humanizing phenomena, so also must the learning enterprise be centered on the processes of learning as elements in a dynamic system of development.

Louise Berman and Jessie Roderick have adopted the term, process-oriented person, to describe that idealized student whose styles and modes of learning have been enclosed within the developmental processes in education.[14] Among the particular traits and expectations for the process-oriented person are self-monitored behavior, other-directed action in social exchanges, and purposeful learning objectives, as well as the acquisition of a wide range of perceptual, communicative, and exploratory skills which allow the person to transform learning operations into meaningful experiences for personal growth. In several respects the objectives of the Harvard general education reforms of 1978-9 are intended to develop such process-oriented persons during the undergraduate years by emphasizing the following goals: (a) clear and effective communication; (b) knowledge of analytical skills utilized in the study of philosophy, history and the social sciences; (c) familiarity with applications of conceptual reasoning in mathematics and the natural sciences; and (d) to not only experience moral and ethical problems at the personal level but to be capable of contributing to the solutions of such problems in the larger contexts and national society as well.[15]

A fuller treatment of the concept of process in education at all school levels has been presented by Louise Berman.[16] The key ingredients must relate the learner as a person who is or can become oriented to the subject fields themselves. Berman identifies the following characteristic qualities contributing to such a total process.

(A) Perceiving - through symbols, impressions and ideas.

(B) Communicating - both verbal and nonverbal.

(C) Caring and loving - an affirmative concern for other beings.

(D) Valuing - the ethical dimension of a social being.

(E) Knowing - the procedures and means for knowing, as well as contact with knowledge sources.

(F) Organizing - awareness of ordering as a human activity.

(G) Creating - reshaping the known and developing the new.

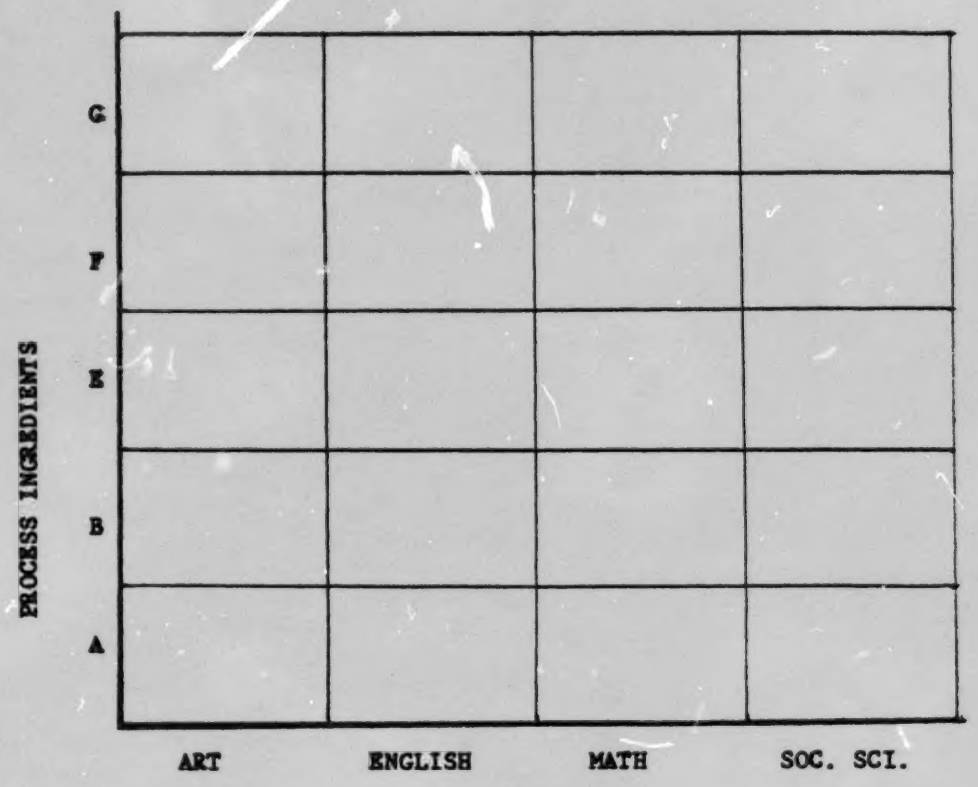
(H) Decision making - both intuitively and rationally based.

This tabulation does not imply an ordering or ranking of the ingredients; but these are interacting variables receiving differing emphasis within the curricular setting. Berman has used a series of diagrams to show the relationships of these process elements to the traditional subject fields,[17] and Figure 1-6 is representational of their general forms. (Items A-H above are entered on Figure 1-6.)

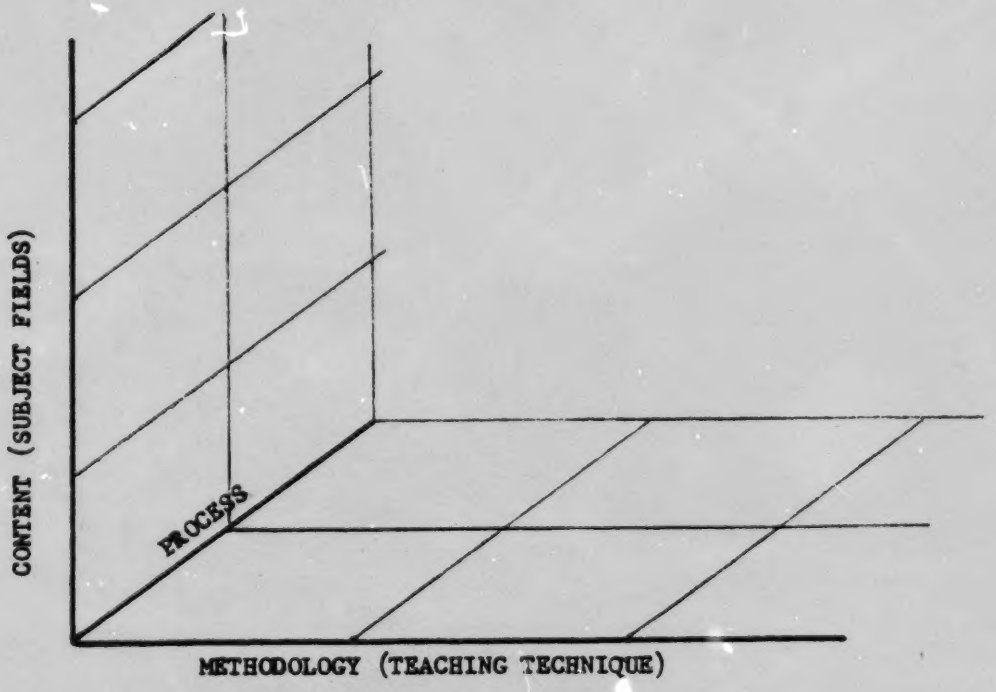
As aids to organization, the plots in Figure 1-6 move a step beyond the Venn diagrams in being capable of demonstrating simultaneous areas of inclusion between several specific elements of process and of program. On the other hand the areas of exclusion between separate elements of a given type become clouded. For example, what exclusive-inclusive connections exist between the elements of knowing, communicating, and creating? The traditional isolation of the separat subject fields remains unaltered, as well. An added positive achievement of the Berman diagrams is their emphasis upon depicting the potential for process orientation in all subject fields and the interdependence of teaching methods with process skills. In one sense these forms might be designated as interloping field plots in which the relationships shown are the regions of common interactions among paired scalar variables (psychological vs. curricular factors). It follows that in such visual presentations of the organizational scheme for the total curriculum, the concept of a developing and directional progression is missing, even though process elements have been included as essential variables in the system.

A recent suggestion by Goldman, Weber, and Noah is that economic input-output models can be applied to curriculum organization.[18] For this purpose, a more restricted definition of curriculum is assumed. The curriculum is formed from specialized and general-integrative course offerings and requires a structure in which teacher-pupil interactions lead to knowledge production and attitude changes. The following two economic models were considered.

(a) A Microeconomic Theory. Input-output analysis and the technical relationships of production functions are used to describe the teaching-learning interface with the specific methodologies of teaching. Two-dimensional plots relate the scalar and rate quantities of the type: learning per unit time vs. selectivity function for teacher quality; and conceptual level of the curriculum vs. teaching time per unit of material. The conclusion obtained is



TWO-DIMENSIONAL PLOT



THREE-DIMENSIONAL PLOT

Figure 1-6. Berman diagrams for process oriented education

that the correspondence between the conceptual level and student comprehension is a pre-emptive factor compared to the specific subject area taught.

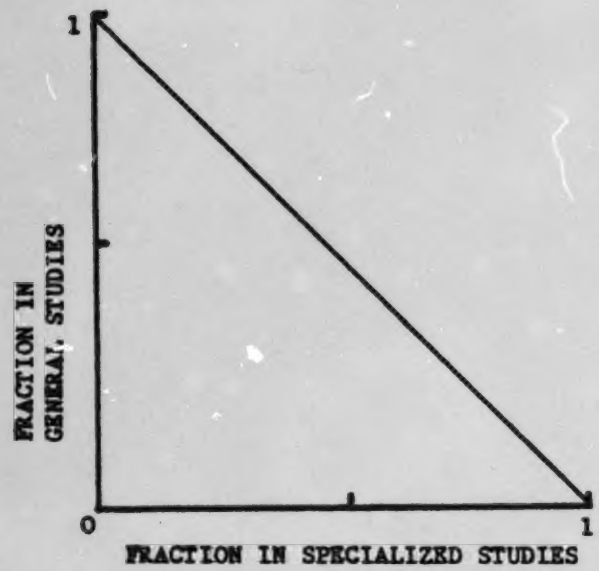
(b) Macro-Socioeconomic Model. Three interacting variables were examined as time-dependent functions: curriculum; social change; and economic-technological change. The rationale for selection of these variables is that high technological change rates cause increasing rates of social change and there is a correspondence between rapid technological change and highly specialized programs of study within the university. Acting cooperatively with this is rising need for interdisciplinary studies with increasing rate of social change. Central to all possible interrelationships among these variables is the time distribution plot of unit slope for the fraction of general studies vs. specialized studies in the total curriculum.

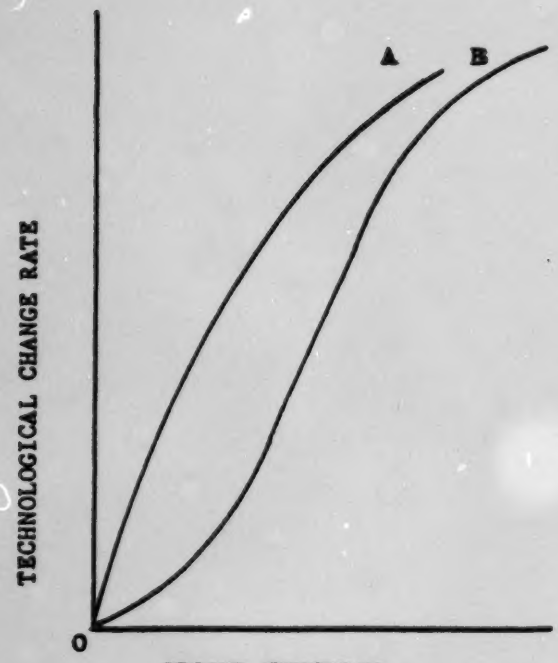
Figure 1-7 is an adaptation of the two-dimensional graphs used by Goldman, Weber, and Noah.[19] The authors assume that the general rate of technological change is greater than the rate of social change, although it is a non-linear increasing function at larger values. However, the degree of specialized studies increases in a semi- logarithmic manner with increasing rate of technological change and is placed below the rate-rate plot. A final and unusual assumption made by the authors is that the functional need for general studies shows only a minor increase over large increases in the rate of social change.

The strength of the economic model lies in the identification of socio-environmental variables influencing the specialized studies-general studies distribution within the curriculum. From this, it is concluded that the extent of expansion of specialization in the curriculum is determined to a large degree by the rate of technological change. The counter determinant on this increase of specialization is the tolerance limitations which the rate of social change imposes when the latter is large. Thus, with such models the rate functions for technological and social change shape the overall curriculum structure and content.

It would appear that the socio-economic models could be applied to the large public university. By contrast, the educational philosophies of the liberal arts institutions have tended to be more idealistic in terms of objectives and have become more person-process-oriented. Therefore, curricular patterns for the two types of institutions for learning will differ in more ways than merely the percentage of time devoted to general vs. specialized studies, and, thusly, different types of models are needed.

As faculty undertake the laborious and stressful task of a comprehensive revision of an undergraduate curriculum, a byproduct for the institution may be a sense of corporate revitalization. However, as the program specifications begin to extend beyond the vague goals of critical thinking and literacy, questions of what other learning characteristics are to be made explicit, optional, or excluded revolve around evaluative questions about significance, both relative and absolute. Likewise, the final plan for a curriculum when examined as a whole may elicit responses from both within and beyond the institution in which a subjective view of significance is articulated by the observer. The simplest (and often kindest) appraisal is to express the local significance of the revised curriculum by comparison to that plan which it replaces, noting the changes and the direction of the changes. And yet, when comparisons are made between goal statements and curricular plans among several liberal arts col-





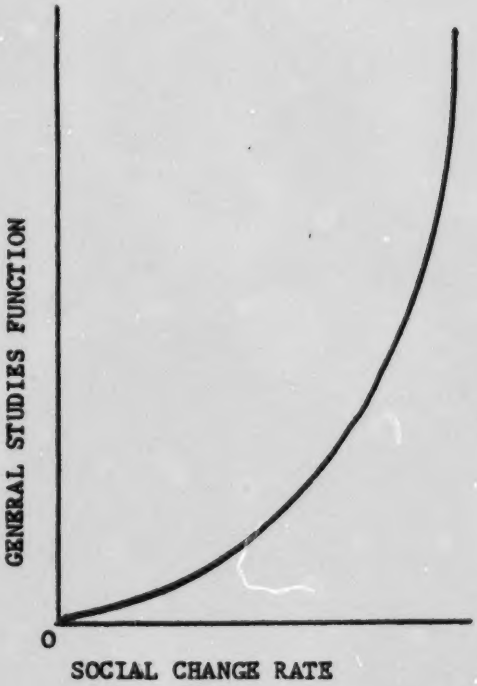


Figure 1-7. Diagrams for economic model

leges, the significance of seemingly minor differences in format or specification of requirements may be completely lost to outside observers.

Any curriculum being developed requires decisions about the significance of most of its determinant elements in both the sense of ranking and in the more fundamental terms of inclusion and exclusion of elements. If the curriculum is a focal point for an overall institutional review of undergraduate education, then the manner by which we translate our high-minded educational goals into the concrete details of a total program is critical to the outcome. Techniques which clarify that process and models which help us visualize what we have done benefit our efforts to specify significance in our plans for liberal education.

As faculty gain experience in the college setting, an outlook often evolves in which the tendency to absolutize the academic departments as the centers of inquiry declines and a larger unity breaking across disciplinary lines becomes more meaningful and/or significant. However, as we attempt to make institutional statements explicit in terms of particular requirements in the curriculum, essential decisions concerning the significance of component parts need to be based upon more than firmly held opinions and verbal arguments alone. Faculty are participants in a learning community and we should become open toward new or unfamiliar methods for approaching the complex problems encompassed within any comprehensive re-designing of a curriculum for liberal education. It is the purpose of this monograph to examine several techniques for the construction of models which might be potentially helpful in our struggles with revisions of undergraduate curricula.

Properties of Models in Education

The development of potential models for liberal arts curricula shares the inherent characteristic assigned by Russell Ackoff to the term, metaproblem.[20] He has noted that every problem-solution system has two fundamental parts: (a) the specific problem requiring a particular solution; and (b) the metaproblem involving the technical improvement of the solution-finding process itself as an implicit function of the problem-solving activity. When applied to the identification of structural relationships in liberal arts curricula, the design problem is to seek a suitable representation for the structural elements within the total curricular assembly. However, the metaproblem, that of modifying the methodology for curriculum analysis, should be examined as well. In looking at the internal structure of any specific liberal arts program the observer is confronted with a great number of variables which are to be combined through models and algorithms in some manner showing common influences and their interrelationships. Hopefully, some variables may approach impalpability and with judgement the system can be simplified to achieve an expositive model.

Any particular format for the liberal arts curriculum is derived from at least the two determinants: objectives and methodology. An overview of the connections between them and the approaches to methodology described in this volume are indicated in Figure 1-8. Although the functions of planning and objectives can be treated in isolation, these are clearly not fully independent factors in shaping the curriculum.

Within the planning methodologies designated in Figure 1-8 the division of the models for curriculum development is made in terms of their origins,

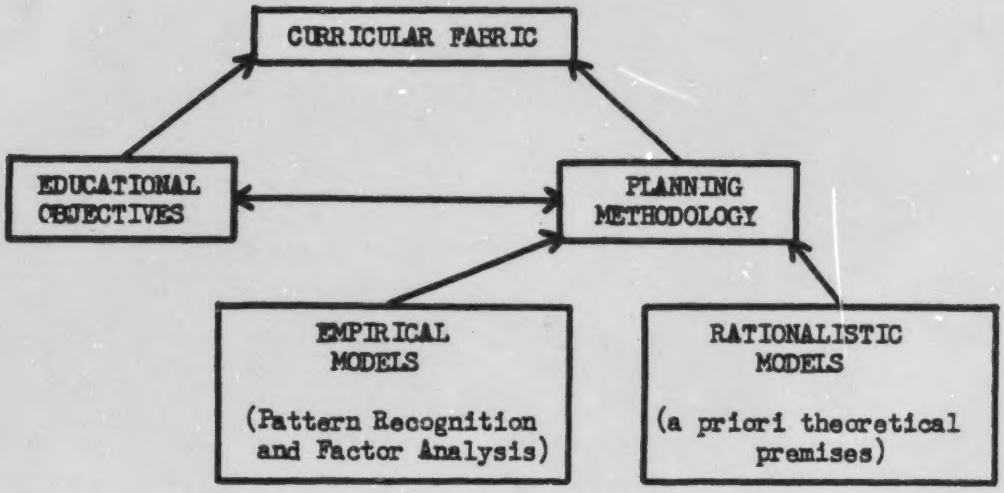


Figure 1-8. Possible approaches to methodology

i.e. empirical tabular data or from theoretical-inductive structures. However, Rom Harré has argued that models for social systems, including educational systems, fall into two basic classes: (a) sentential models in which verbal statements in a given model are linked by a direct correspondence to the sentences used in a full description of the original process or phenomenon; and (b) iconic models having a structure, form or function which mimics a particular real object or process.[21] The latter may be pictorial in their simplest form but these can be extended to the conceptually abstract structures of modern scientific theories as well. For the sentential model to function as an explanatory representation, some acceptable confinement or reduction of the number of possible sentences abstracted to the model is necessary if the model is to be a concise representation of the original sentence set.

Although the authenticity of the sentential model is easily checked by direct comparison to the original sentence set and by analysis for likenesses to and differences from that set, the iconic models pose more complex problems with respect to verification. Harré has correctly emphasized the importance of examining specific iconic models for their testable predictions and the adequacy of their simulation of observed functions, as well as their more obvious, direct replication of the dominant characteristics of the real phenomenon or form. In trying to expand iconic modelling procedures to educational problems it is these criteria of authenticity which are the most difficult to implement; and this is especially so in the area of curriculum organization.

The construction of hypothetical models for an overall undergraduate program falls in that subspecialty of education traditionally called "curriculum theory" and implies a macroscopic examination of assumptions and structural elements of the learning system as a whole. Morris and Hamm have observed that such curriculum theories are characterized by alternative schema for the organization of knowledge which can be universalized in principle; and these share an ontological basis in that each is supported by or derived from a particular foundational view of the ultimate worth of learning as an ingredient of being.[22] If one uses a structural basis for reviewing and classifying curriculum theories as Morris and Hamm have done, then the following major types of theories can be identified as prominent at various levels of education in the present century.

A. Empirical Structure. The content of the curriculum stresses preparation and training to meet specific vocational needs of the contemporary society. Empirical data measuring present and anticipated needs of the job market are the starting points for organizing this program of vocational-professional education, whether in the community colleges or in the pre-professional areas of the four-year institutions.

B. Logical or Rational Structure. The shape of the curriculum is determined by the organization of the academic disciplines and it is formed by the disciplinary specialist who knows the sequential development required within the given discipline and can justify the supporting areas for study. In this type of structure the faculty of the graduate and professional schools themselves ultimately exert the largest force shaping the undergraduate curriculum.

C. Cognitive Structure. Here the organization of the curriculum in all of its parts is built upon a theory of knowledge which includes not only knowledge structure but also models for cognitive development by the learner. The cur-

riculum is envisioned as an interactive system operating between the knowledge sources and instructional mechanisms; and, thus, a more unified program is possible than in types A and B.

D. Conceptual Structure. This approach to curriculum planning begins with some psychological theory about fundamental processes for learning and evolves a structure emphasizing instructional methods which operate throughout a lifetime of learning. The focus is upon the developing and unique individual learner; and, as a curriculum theory, the conceptual structure approach has been applied most extensively to elementary education.

E. Existential Structure. The curriculum has the least formal structure in this case and is intended to operate in an environment of learning resources in which each individual learner creates personal learning experiences (and a personal curriculum) from the individualized choices of interests and actions. Although each individual is assumed to be free to choose among alternatives and is self-motivated, that person is within a social situation for learning which compels responsible and ethical actions as well. The existential structure focuses on both cognitive and affective behavior, and confronts value questions more directly in learning than do the preceding curriculum theories.

When placed in the order given above, the types of structural theories exhibit a broad shift in the relative emphasis given to the knowledge content of the subject fields compared to the development of the learner as a person. Within this context the shift from A to E is high-to-low with respect to the disciplinary emphasis and the reverse trend occurs with respect to the self development by the learner.

In attempting to develop additional models for the undergraduate curriculum certain fundamental restrictions within the model-building enterprise should be recognized. Any satisfactory model exhibits some essential analogy to the real phenomen, and those features held in common by both the model and the real system become the only isolated variables considered to have primary importance. However, such a model is not merely an approximate description of reality in the formal deductive sense. Hopefully, the superior model can be extended or generalized, and modifications can be made where required by empirical tests. The descriptive character of the model may assume a mathematical form which extends the analogy through factual identities, prediction, and embellishment. Although model construction requires a restriction of the real system and a degree of idealization, the similarities between the model and the real system must be described by appropriate defining terms, symbols, and operations. For educational processes, it is clear that several mathematical models can be used to depict the real situation; and each of these can contribute to a better understanding of some aspects of a problem. It is possible that there may not be a "best" model capable of fully representing all major facets of the real system. An important contribution of model building may be simply the recognition of analogous relationships between the real process and its symbolic form.

The analogy drawn between a given model and the real system is thusly limited by the model-builder who determines its context as well as its final assembled design. One's structural model will incorporate the essential relationships between its component parts but must minimize any distortions hidden within the analog for the real pattern. At the undergraduate level the

component parts of a curriculum are essentially substantive in the sense that they include as a minimum such specifics as goals for liberal learning, subject or disciplinary contents, and appropriate strategies for instruction. Any curricular analog for such a real system is clearly incomplete if it fails to extend beyond the identification of the parts to a comparative examination of relationships among them using meaningful language and operational symbols. Representative of such failures in curricular design is an area distribution requirement in which there are no clear connections or demonstrated interrelationships among the parts of that distribution; and, therefore, the subject area subsets become disjoint with respect to stated objectives for liberal education. In that instance the utilization of simple Venn diagrams would be sufficient to visually depict the fundamental weakness of the planned curriculum.

The languages to be used in the formulation of constructs pose special problems for the field of education. It has become increasingly evident that the imprecision and ambiguity of our common language is quite limiting in attempting a phenomenological analysis of education as a process. As one option, we may use an analogy in common-sense language in order to elevate certain intuitional elements to a meaningful level; however, at the same time that analogy resembles the metaphor in that it is makeshift and a substitute for a more accurate or genuine description. Of course a language is indispenable for the creation and interpretation of our hypotheses; but it is important that we acknowledge that purely common language has a decreasing utility in simulating educational phenomena as complex as curricula. Greater language precision is required, and it must be in the form of a controllable language which will allow exactness in showing connectives, reduction to essentials (abbreviation), and manipulation for prediction if possible. An analogy can be a method of discovery but we must not overlook its incompleteness and lack of a fully unique correspondence to the real phenomenon.

An emphasis upon precise and logical patterns of thought immediately suggests a structuring of statements in mathematical and deductive forms, which follow specific rules for the manipulation of their symbols. Although the primary relationships then assume a formal exactness, such a certainty evolves only from the deductive relationships among the symbols themselves. The real phenomenon always introduces a haziness or uncertainty into the symbolic depiction of each element even if that element can be expressed as a measurement.

In constructing a model for an educational system by using language forms derived from mathematics only selected aspects of the real or phenomenological world are extracted and symbolized within the model. Where the descriptors of the real world are numerical data sets, mathematical models which are termed <u>discrete</u> can be applied to the examination of possible groupings, of probable outcomes, or of appropriate decisions implied by the selected finite information sets. However, Fred S. Roberts has represented the overall interplay between the data-base and the mathematical model as a cyclic process in four stages, and a modified representation of his viewpoint is shown in Figure 1-9.[23]

The cycle begins with the empirical data-base (state 1) which describes the real world condition or problem and, from that finite information set, a minimal subset of variables is abstracted and translated into mathematical language. Then, purely mathematical assumptions and rules are used inductively to formulate a generalized model as the second structure (state 2) in the model-

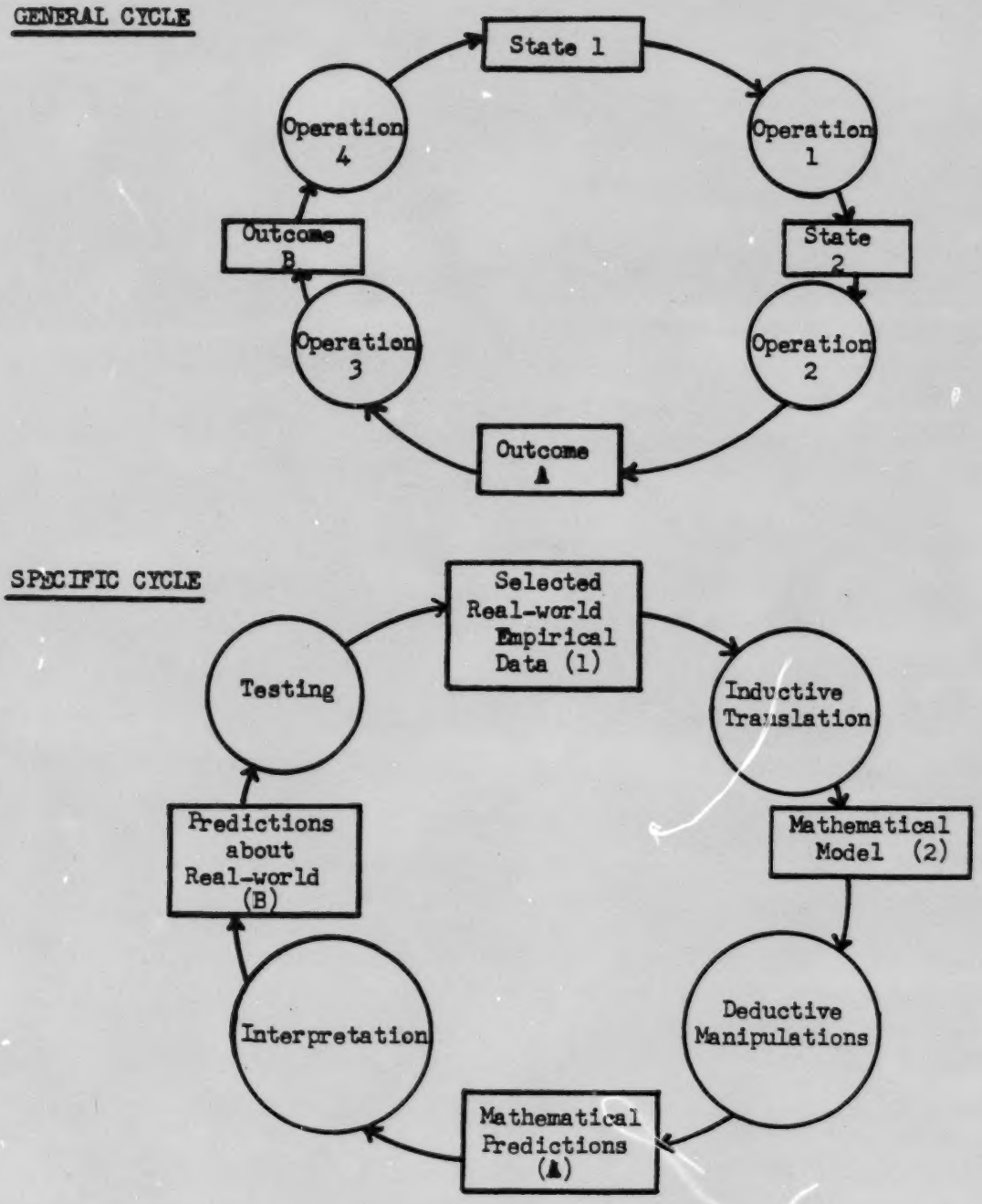


Figure 1-9. Schematic for mathematical modelling cycles applied to social phenomena

ling cycle. Various mathematical tools can be applied to the new model in order to obtain a range of deductions which are implied or conditionally follow from the model, and these logical deductions are restricted initially to mathematical predictions (as outcome A). Once the mathematical predictions are obtained the next step is to re-make those predictions in terms of conclusions about the original real world problem to yield a second outcome from the model (outcome B). The final operation in the cycle is that of testing the predictions about the real world problem against an existing or new data set, and, using statistical limits to express the reliability of these tests and ultimately of the proposed model itself.

The cycle can be repeated in an effort to improve the explanatory potential of the model or the quantitative reliability of its predictions about the real world. Although these iterations may lead to a more reliable regeneration of the data set, such empirical models remain probabilistic regardless of their axiomatic refinements. On the other hand, the concept of the modelling cycle does not exclude the total abandonment of a very weak model. Likewise, the development of a model which is more descriptive of an expected range of outcomes may occur at the expense of the model being numerically specific in its predictions. For curriculum problems, the objective for the cycle cannot be unequivocal certainty but rather to provide a procedure by which the dimensionality or scope of the educational system is de-limited and the logic of the inquiry is visually specified.

One important aspect of this view of modelling as a cycle is the assumption that any specific model is a tentative structure during the early stages of its development. Certainly, the general experience among faculty involved with undergraduate curriculum development and reform demonstrates that major difficulties are centered first upon the prospects for revisions of the model program before its final adoption and second upon the anticipation (prediction) of areas of weakness within the model itself. The application of modelling cycles to curriculum problems should prevent those failures arising from overly rigid initial formulations of only a single model for liberal education when the intent is that alterations to it will be restricted to merely editorial matters. As a procedural concept, the cycle allows us to more objectively compare alternative models both philosophically and empirically with respect to the expected and the real outcomes of learning in advance of any firm actions directed toward early adoption of a specific curricular plan. Clearly, any new curriculum will encounter unanticipated difficulties as it is first implemented and some means of monitoring the program is essential in order to make adjustments in the model as a tentative guide to educational practice.

The search for increasing precision in educational hypotheses is directed beyond the correlational or descriptive roles toward predictability. An important aspect of prediction is that it does not merely regenerate the original observations but it also must have a type of extended fertility to be able to show deductive connections with unknown dimensions of the phenomenon. In its simplest form prediction becomes possible when we utilize those operational definitions which stand for quantitative concepts and measured numerical values. In this sense the prediction takes on the characteristics of the rules for measurement and it conforms to the expectations of the operationist's view in the sciences.[24] By contrast, for those variables which are difficult to quantify, the deductive formalism typifying mathematical logic can still provide predictive conclusions applicable to new or unknown facets of the phenomenon under review. Thus, we can search for predictive characteristics

within semi-quantitative models of educational processes if the fundamental connectives between variables can be clearly identified.

One way of analyzing the quite complex problem of designing a learning system in which human behavior is to be modified is to attempt to factor the total problem into smaller units. Thus, a total learning system can be resolved into the parts: diagnostic evaluation; behavioral objectives; learning strategies; learning resources; etc.; and the assessment of such smaller units can readily yield particular solutions. However, it is all too easy to be satisfied with the detailed manipulation of the smaller unit problems while overlooking the fundamental connective links between the factored units and the total system. The content of the present monograph is directed toward the examination of the larger design problem for the total curriculum while viewing that problem as being composed of interrelated smaller elemental units.

In the early stages of the development of any comprehensive model a reduction and simplification of the real system is undertaken. The formulation of starting analogies assumes that there are certain primary features and isomorphous connectives which can be abstracted from the real phenomenon to the model. According to William Morris, there are several options which may be utilized in this simplification.[25]

(A) Reducing the number of variables to a minimal set.

(B) Suppressing randomness in the system through a quantitative ranking of the variables.

(C) Setting up a symbolic language in either sharpened verbal definitions or mathematical form.

(D) Identifying obvious connections, assumptions, and limitations relating the variables and definitions.

In order to strengthen the simplified model it is necessary to explore its relationship to other hypotheses concerning the problem which may have already been proposed and to examine the model for possible modifications.

It is clear that the creation of a model assists the investigator by organizing the relevant observations into a unified whole. However, the model is equally important in providing a basic framework for the formulation of hypotheses. The model in education must illustrate the hypothetical relationships through appropriate symbols in a linguistic or mathematical form; and the symbolic pattern for the simplest visualization is most frequently presented on a two-dimensional surface or as an x vs. y graph. That visualization of relationships is essentially structural and may suggest an additional hypothesis connecting a new observable property or also an extra hypothesis containing a new theoretical concept. Such a model appears to point toward certain ways for its extension; and, as with an analogy these predictive features of the model should be considered only as suggested extensions of uncertain significance and as highly tentative.

Whether verbal or mathematical symbols are used, the interpretation of the model must also identify those points where the analogy breaks down. Thus, a workable model for a liberal arts curriculum will expand our under-

standing of the phenomenon of education through the separation of variables while carrying within its structure recognizable imperfections and limits. At the same time it must avoid the introduction of extraneous factors into the description of the real process which may lead to incorrect or confusing predictions.

The several techniques appropriate to the modelling of curricula included in this monograph share the same impetus as those cross-disciplinary studies which have in recent years been labeled "hypergraphics". This term has been used to emphasize the focal point for commonality among the visual arts, sciences and technologies through the transformation of static information into visual and geometrical forms.[26] Such transformations generally involve complex multi-dimensional (i.e. multivariable) information which must be reduced to visual and spatial descriptions represented by two or three-dimensional geometry. The resulting communicative effect of that operation can be important to our understanding of complex and intricate concepts through the visual demonstration of connections between real variables. There can be no argument about the complexity and variability (and n-dimensionality) of liberal learning; and, therefore, our activities with curricular design and analysis can benefit from an expanded application of procedures for both simplifying and visualizing the fundamental though complex interrelationships in liberal education.

Although such an analysis of liberal learning begins with dissection, the rational reconstruction through curricular models need not be merely a repetition of the original assembly. Our analysis should succeed in separating the essential givens from the accidental as our imaginative use of variations reforms the thematic core for liberal learning and projects visually the unity as well as the ambiguities within our educational system.

In the succeeding chapters of this volume several approaches to model construction will be examined, and in each instance special emphasis will be given to the visual significance of the model along with its conceptual origins. This symbolic role for the graphic images as abstractions from the real educational systems being reviewed will require the support of a more precise and hopefully more accurate vocabulary as well.

As one option in curriculum development, the interweaving of the visual with the symbolic and the verbal arguments applicable to the appraisal of various forms for liberal education will yield a more concise and often more effective description of the processes involved than methods based upon verbal arguments alone. Specific critical and analytical alternatives considered in the sections which follow are:

(a) applications of graphic depictions of the continuum in order to show the range of possible or likely alternatives between terms which are polar opposites;
(b) Venn-Euler diagrams to represent inclusion-exclusion phenomena as well as areas of commonality in learning processes and liberal education;
(c) the uses of flow charts for describing contrasting models for integrative learning;
(d) pattern recognition techniques providing an empirical methodology for the identification of elemental components to be incorporated into a general system for liberal learning;
(e) a variety of vectorial models for projecting the interacting and con-

trasting forces which determine the structure of liberal arts curricula;

(f) rudimentary concepts drawn from matrix theory which provide useful ways for a re-structuring at a fundamental level of the elements of generalization in the curriculum.

Although some of these techniques for model formulation may be unfamiliar to many faculty members and may seem overly simplified to the specialist, it does not follow that such procedures are unprofitable or unimportant in our quest to re-organize undergraduate curricula for liberal learning. A variety of tools need to be examined if we are to interpolate the developmental meta-problem of liberal education.

Chapter II

VECTOR MODELS FOR CURRICULUM ORGANIZATION

In either representing an exsiting curriculum by a model or developing a new curricular organization word statements about philosophical objectives and the nature of the selected learning processes are usually early ingredients in any planning document for undergraduate liberal education. The objectives may be elaborated in operational terms and in course content. Likewise, patterns of instruction along with the desired educational experiences may be specified in some detail. Although characteristics in common among varied curricular plans can be sensed in part from these verbal planning documents, considerable analytical skill is often required in order to identify the truly unique and fundamentally important differences between curricula: past, present, and newly proposed.

One of the simplest and easiest options devised for the general education portion of a college curriculum is the area distribution requirement system, a format with a relatively long history in many liberal arts institutions. Recent efforts to reinstate distribution requirements in the colleges seem to repeat the patterns of the first half of this century with an emphasis on western civilization and traditional humanistic studies. However, it does not follow that such programs which are so familiar to faculty are necessarily the most appropriate ones for all current undergraduates nor should these plans be viewed as the only potential structures for the stipulation of the general studies component in future curricula intended to stimulate liberal learning.

There have been at least five nonequivalent underlying emphases used in the construction of liberal arts curricula in the past,[1] and trends toward requirement modifications have been summarized by Dressel and DeLisle.[2]

(A) Unity Among Fields. Although each of the several subject fields has its own uniqueness in knowledge data, techniques, and assumptional foundations, it is the intent of this approach to identify unifying concepts, methodological similarities, and historical-discipline similarities and historical continuity, by comparisons among subject fields. Educational resources and course formats are designed to produce an integration of related academic areas without concern for the provincial requirements of departmental major programs.

(B) Field Survey. A certain number of credits are given in courses providing a broad introduction to the scope and subject matter of particular subject fields. Even though the ideal of a comprehensive overview of important aspects of the given discipline cannot be achieved, the thrust of these courses has boundary restrictions in "principles, concepts, and facts".

(C) Cumulative Distributions. The goal here is not unity but rather examined diversity. Additivity of credits obtained outside of the major field of concentration forces student attention toward other subject matter and contact with other disciplines. Any critical comparisons between subject fields must be incidental to the fact that the available courses are essentially first and second level departmental courses serving the needs of the given discipline.

(D) Problem-Solution Theme. Particular contemporary or historical problems

are used as the focus for the general courses, and the approaches used by all relevant disciplines are considered in seeking or examining suitable solutions. The scope of problems or issues can vary greatly, but in general terms the locale is human society. Thus, the performing and visual arts receive little attention, along with mathematics and language.

(E) Axiological Unity. The general courses required of all students minimize divisional fragmentation of the spectrum of knowledge and place the individual segments within a unifying framework of values and belief. In some of the church-related colleges these courses are intended to be supportive to the larger vocation of the Church in society. However, a value-centered thematic unity is found in general education courses among some of the private non-sectarian colleges also.

Harold Taylor placed patterns for the general education segment into three philosophical catagories.[3]

(A) Neo-humanist programs - stressing Western cultural history and dividing the requirements among the social sciences, natural sciences, and the humanities as essential subject fields.

(B) Rationalistic programs - having their emphasis upon the progressive development by the student within the areas of value and belief systems and aesthetic awareness.

(C) Instrumentalist programs - usually individually selected broad-ranging programs, centered on the student as a creative learner and are process oriented.

The order assigned to the above classes is one of increasing curricular flexibility and corresponds to one of a decreasing role for the disciplinary majors in stipulating particular general education requirements. When placed in that order, the result represents the evolutionary sequence for general education during the past four decades as well. Guidance assumes a special and important function in instrumentalist programs.[4]

The rationalistic and instrumentalist programs in the classification scheme of Taylor are equivalent to what Arthur Levine has included within the label "progressivism" in general education requirements.[5] Although this simpler label may be a historically correct description for the student centered curriculum, it is not particularly useful as a meaningful philosophical term for purposes of distinction. On the other hand, the several forms of core requirements found in many general education programs have been aptly grouped together by Levine as "essentialist" with respect to subject matter content and their assumed universal importance. The application of the term, core requirement, needs to be limited to a specified minimum set of common educational experiences and competencies expected of all undergraduates in liberal arts programs at a given institution. Thus, core requirements are not equivalent to the cumulative distribution requirements in terms of their intended objectives nor in their organization. The latter are usually stated as a specific number of credits within subject fields or grouped disciplines, but the student can meet the separate requirements by electing courses from a list of "approved courses" in each area.

Each of the above classification schemes clearly identifies the starting point for planning the particular curriculum and the philosophical stance in each is also fairly clear. However, like the pragmatic approach to structuring the curriculum, these are sufficiently diffuse to be comprehensive and yet too vague to lead to specific modes for implementation. Although initiation of program reform begins with a clearly stated set of objectives, the development of a derivative format for the curriculum poses a more complex and detailed problem.

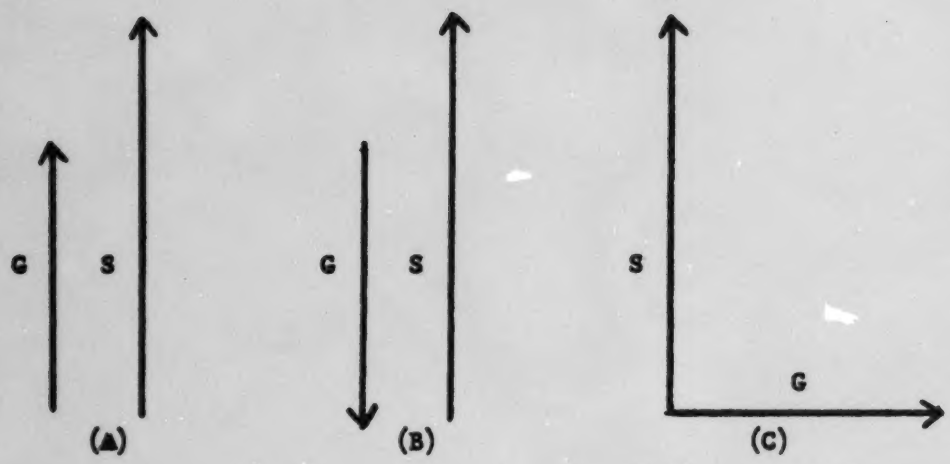
In the following sections the interactions between general education and specialized education in liberal arts curricula will be examined from the viewpoint of possible vectorial alignments for the differing structural forces. As models, these analytical devices may appear crude and oversimplified; however, by focusing on essential and dominant interactions, the models depict sharply the philosophical similarities and differences between various plans in use now and in the recent past. Also, these visual constructs suggest correlative deductions more easily than do word statements of program emphases like those itemized above. The key assumption in the vectorial models is that liberal education is a process, but one determined in large part by the continual interaction of identifiable forces.

Simple Linear Models

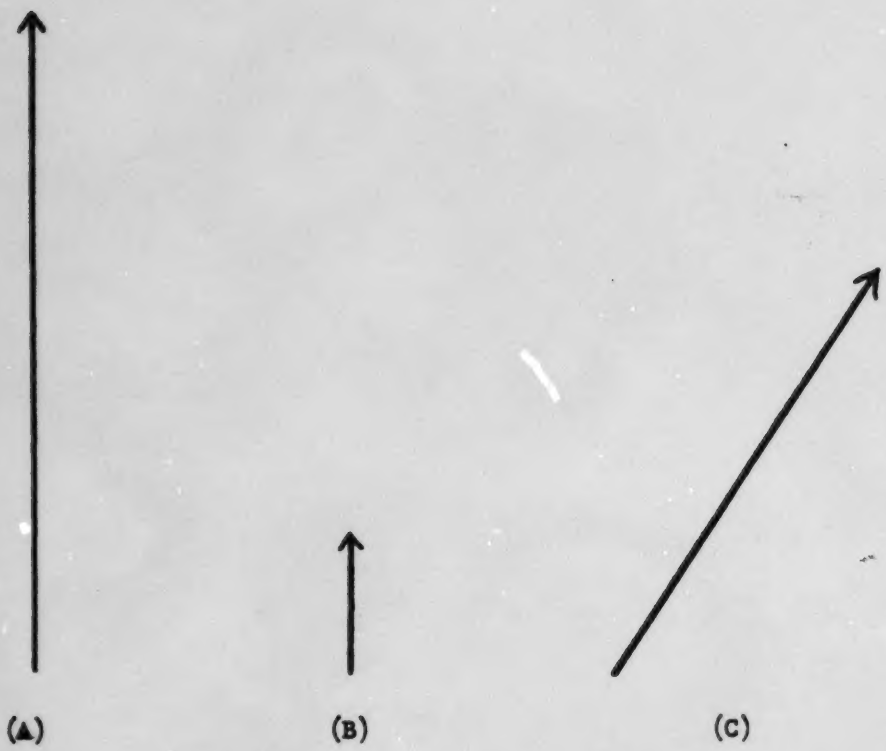
Among the several structural approaches to liberal education, two underlying elements are held in common: that of breadth (or generalization - G) of knowledge; and the other of depth (or specialization - S) within a given subject field. Frequently, these elements have been viewed as operating directionally, sometimes in parallel, sometimes in opposition, and in other instances oriented in entirely different directions to each other both within the general studies and departmental programs. Thus, regardless of the particular plan used at a specific time, the fundamental role of these two elements has been vectorial in that the physical characteristics of both magnitude and direction are met. The possible interactions are shown in Figure 2-1.

Somehow the resultant or vector sum for these interacting forces is expected to constitute liberal learning and is usually contrasted with the professional training programs in which vector G has minimal length or may approach the zero limit. Thus, generalization is not being represented as bigger (or better) than specialization deriving from the various disciplines, but only as being different from specialization. One of the essential differences lies with the objectives (i.e. directional orientation) for the learning activity: the anticipation that individual learners can master a range of communicative and analytical skills common to many areas of study as well as expand their value sensitivities and the scope of their social concerns.

Of course, other comparable terms can be substituted for the counterpoised pair, generalization and specialization, without loss of the conceptual distinctions implied here. For example, Yale College among others has used "concentration" to symbolize the depth dimension and "distribution" for the breadth and integrative aspects of their undergraduate curriculum. However, for the purposes of our present introductory discussion, the generalization vs. specialization terminology is sufficient for a tensional description of liberal learning.



VECTOR COMBINATIONS



RESULTANT VECTOR SUMS

Figure 2-1. Linear vector models

Curricular patterns dominant in the liberal arts institutions of the late 1800's and early 1900's kept the generalization and specialization vectors vertical, parallel, and nearly the same size. By imposing rather rigid criteria for acceptability upon both subject fields and major fields allowed in the curriculum, vector G became the larger force restricting the total pattern.[6] However, in the absence of any separate courses to serve the general educational function in the curriculum the introductory and second level courses within departmental programs were expected to be of sufficient importance to all students that breadth of learning and interests would follow. The possibility of liberal education being a vector sum greater than G or S separately was implicit in the granting of an arts degree as opposed to a science degree during that historical period.

Evolving from this essentially parallel vector model were various attempts to alter the relative lengths of G and S and to increase the number of subject areas in which specialized majors were offered. This was in part a response to growing competition from the public universities and the land-grant colleges, although university trained faculty within the liberal arts colleges were attacking the specific content of the elements of generalization. During the first quarter of the present century, the classical liberal arts requirements in ancient languages, religion, and philosophy were replaced by introdutory courses in modern languages and the social sciences. Vector G still tended to be operating as a parallel vector, and vector S gradually increased in length and relative contribution to the total sum. However, departmental programs increasingly inserted elements of generalization into their own majors by adopting first and second minors in closely related subject fields. The latter aspect was implicit in the patterns in a number of pre-professional and pre-graduate school curricula and was easily compatible with the liberal arts tradition. These minors themselves still remained parallel in vector orientation.

By contrast, at the departmental level within the university setting the predominant conclusion was coming to be that G and S were in opposition, that generalization hindered the needed extension of the specialization in the major field. From a philosophical point of view, arguments for the opposition of the G- and S-vectors have been presented by Bell in these terms: (a) specialization has a factual-sequential organization (or what should be known); and (b) generalization stresses the process and conceptual inquiry (or how one knows).[7] Thus, liberal education requires a reconciliation of the two antithetical vectors, and liberal learning is not synonymous with generalization alone.

Most of the liberal arts colleges realistically circumvented the opposed vector model as an institutional plan by declining to compete with highly specialized university degree programs in engineering fields. Yet this model was and is now very much a part of the fine arts departmental majors in the smaller institutions. This internal tension mirrors a secondary vector in all of the subject majors, a vector which contributes to the total S, namely the vertical element of basic skills and increased field competence as a progression within the area of specialization itself. Thus, the experience of the liberal arts colleges shows that the vector S not only has length (or magnitude) in itself with respect to the defined scope of the subject areas, but it has directional components whose interactions with generalization cannot be ignored.

Derivative from the parallel-antiparallel G-S vector alignment is the plan for area requirements as one approach to general education, originating at Harvard in the early twentieth century. The usual distribution shown in Figure 2-2 required nearly equal numbers of credits to be obtained in the areas: foreign language; humanities; fine arts; social sciences; and natural sciences. The student with little advisement chose by preference the particular courses needed to fulfill the requirement, and the bulk of the selected courses lie in the lower levels of the departmental vectors. In this arrangement no core unity in subject fields was expected. The strength of the plan is found in the fact that the linear sum of the G-vectors always exceeds the S-vector, a feature common to all later formulae for liberal education. Modern representatives of the area distribution scheme for generalization are the degree requirements at Earlham and Macalester colleges. At Earlham College these include two courses in each of the areas: history, English, social sciences, religion-philosophy; four in natural sciences; one in fine arts; and specified credit in foreign language.

An obvious weakness of this plan is that with few exceptions the G-components are really only segments of the indvidual departmental S-vectors; and, as such, they evolve little or no integrative function, but tend to remain isolated segments in the student's undergraduate experiences. The exceptions would be those lower level departmental courses stressing the relevance of the discipline to man and society. (See Appendix 1 for a specific case study.)

It was the prestigious private universities that re-designed liberal arts programs during the 1930's and 1940's with the goal of making general studies more horizontal and directional. The Chicago, Columbia, and Harvard plans had in common the development of general S-vector components, and the intent was to arrive at a broadly integrated unity for what became a horizontally directed G-vector. (See Figure 2-1.) The latter was deliberately horizontal in an attempt to pull away from both narrowly specialized courses in the major and minor fields, and the inherent vertical sequencing of such departmental courses. The G-vector was no longer composed of simple S-vector segments, but became a totally separate entity in terms of direction and content. The new courses were served by a separate faculty of "generalists" and the special function of general education developed an independent existence.

Unique characteristics of the Columbia plan were minimal attention to the requirement of a major (actually optional) and carefully formulated interdisciplinary general courses during the lower college years in the humanities and contemporary civilization. The baccalaureate program at the University of Chicago had a two-to-four year comprehensive general core inclusive of the three areas: social sciences; humanities; and natural sciences. Although not a part of the original plan at the University of Chicago, a departmental specialization was an integral part of all four-year liberal arts degree programs adapted from it at other institutions. The Harvard requirements never abandoned the departmental major, but did specify a given number of extra-departmental courses having a general education-type of organization and content.

The right angular orientation of the S-G vectors remains in many current general education plans, and, from a quantitative viewpoint, the S-vector is the shorter function in most liberal arts programs. A major limitation which this model shares with area distribution approaches is that the general or survey courses may sacrifice content sophistication for coverage. Likewise, the

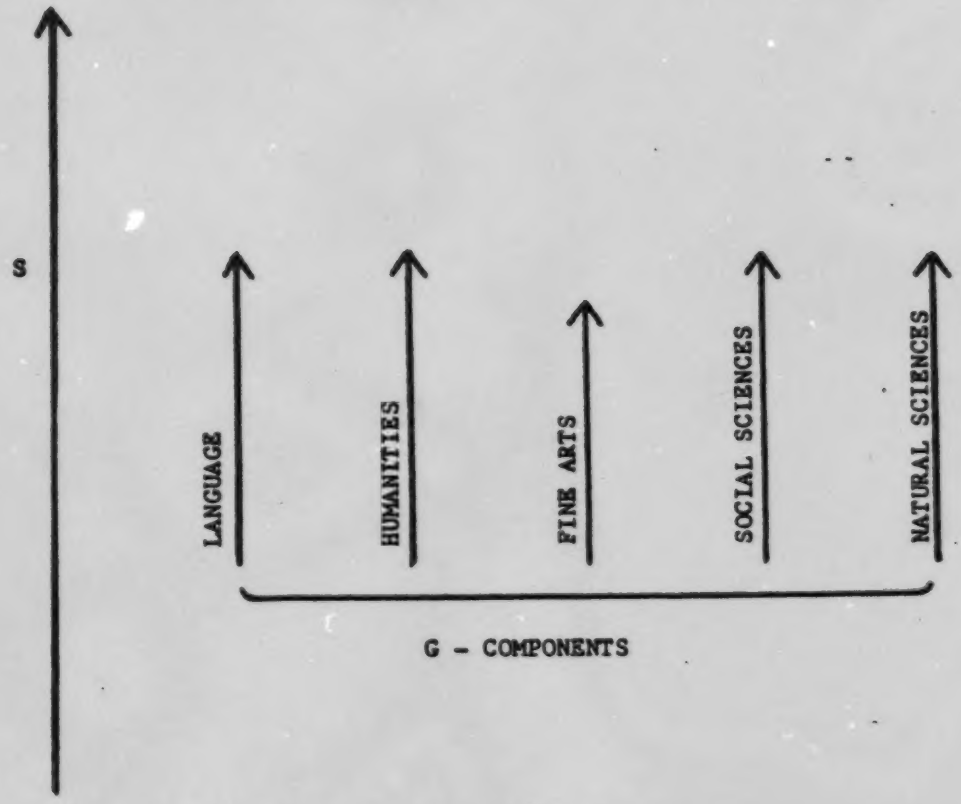


Figure 2-2. Area distribution pattern

value framework of the faculty members involved tends to give a form of exclusiveness to general studies and to reject the relevance of research as an element of the learning process. A real strength of this vector oriented model is that the excitement of interdisciplinary crossover in the general studies program can give feedback to the specialized majors.

For all three vector alignments shown in Figure 2-1, the resultant vector sum implies a goal directive which does not lend itself to quantitative evaluation. Standardized tests provide direct methods for measurement of the magnitude of the separate S- and G-vectors, but these tests can do little with respect to inferences about the length of the resultant or even its directional angle. The nearest approach to evaluation of the resultant of G and S is the problem-solution unknown in which the student must draw upon an integration of all of his intellectual skills and resources; however, this test method has been more frequently applied to the major field than to general studies.

Nonlinear Models

The bisectional cleavage of the total liberal arts program into generalized and specialized areas has been extended by a number of the more recent curricular structures beginning with the Harvard revision of 1945 and developing to the Beloit and Florida Presbyterian plans. In its earlier form this program involved a designed sequence shown best as a diagonally bisected rectangle in Figure 2-3. Here, the rectangle is essentially a time frame in which the horizontal coordinate shows a distribution of credits giving a constant sum. Thus, the amount of time devoted to generalized studies decreases linearly in the time progression,[8] and, conversely, specialization increases. A model of this form is not a truly vectorial one; instead it is vectorial in terms of the G-S structure and scalar with respect to course distribution, an arrangement having limited analytical potential. On the other hand, such structures direct greater attention toward the component parts entering into the construction of both the G- and S-vectors, and in one sense each assumes horizontal-vertical character.

A proposal by Bell re-states in these terms the breadth dimension of the area of specialization as an integral part of mastery of the discipline: (a) an introduction to the historical and philosophical pre-suppositions of the discipline; (b) extension of the discipline in the technical sense; and (c)[8] operation of the discipline in the wider context of the activities of man.

For the separate entities of generalized and specialized studies, there are the ideas of vertical progression and horizontal integration at each succeeding level of encounter. Even in the subject majors themselves, breadth and content unity are now stressed as essential ingredients of the lower level courses, although senior level work acquires the usual specialization. The interaction of these component parts can be diagramatically represented by the paired triangular model of Figure 2-4. The general studies triangle is wider and the degree of specialization lower, even though the total area of the triangular array equals or exceeds the departmental studies. On the other hand, departmental generalization vectors (G) are more closely confined and the single S-vector is more extended. A conical structure (or its planar projection) has become a fact of life in nearly all departmental major programs in present day liberal arts curricula.

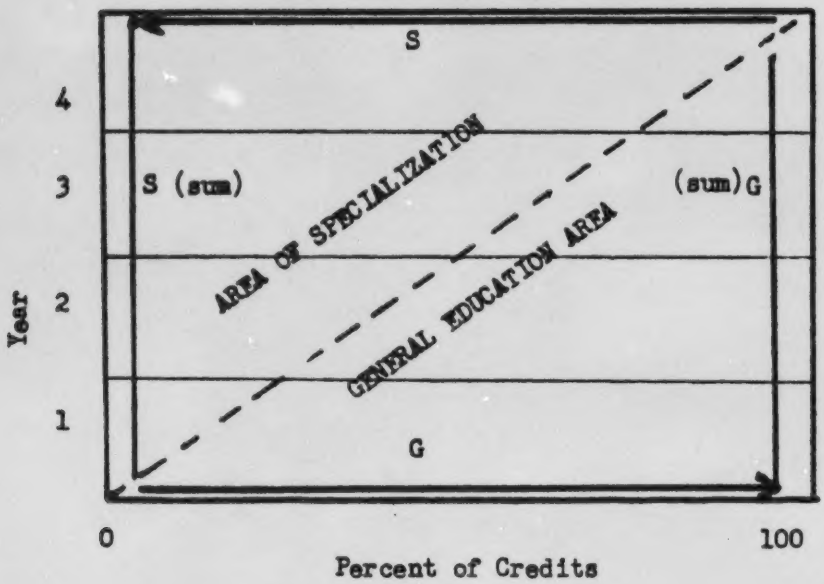


Figure 2-3. Credit distribution plan

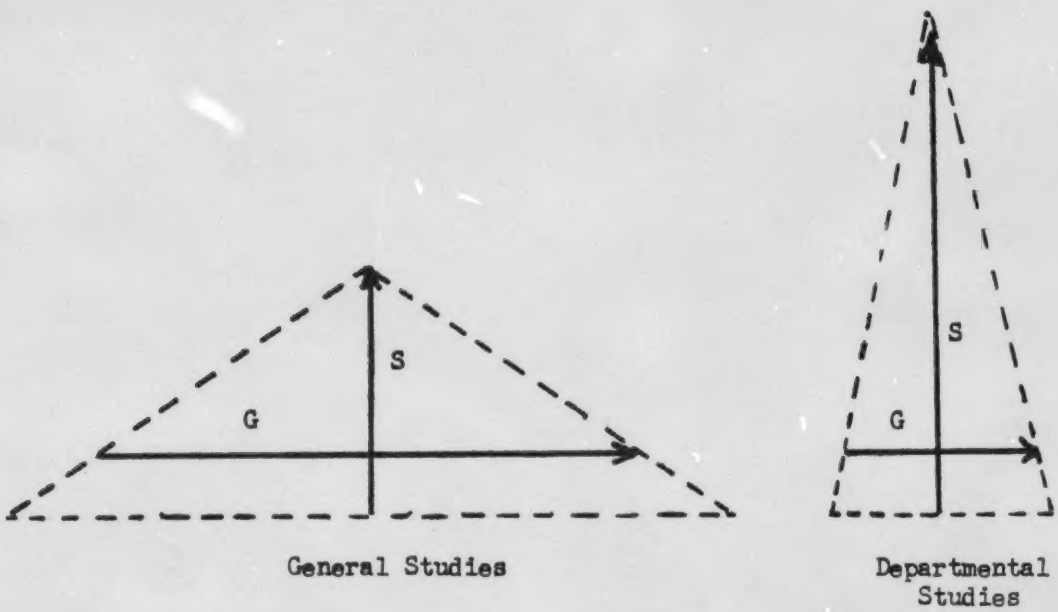


Figure 2-4. Triangular pattern

The triangular model assumes that an identifiable common foundation structure exists in methodology and philosophy among some disciplines. Thus, it is possible to construct a series of unified but parallel G-vectors (limited only as parallel G-vectors of varying lengths) in the general studies triangle and not be restricted to a survey-type content. The mathematics-natural sciences component easily illustrates this element, as does the visual arts-music-drama sequence. This foundation concept can be applied to the more restricted G-vectors within the departmental studies triangle as well, although usually the content gives greater emphasis to knowledge tools and skills necessary for successive steps in the process of vertical specialization than to unity of epistemology. However, only rarely do the foundation courses in the general studies areas appear in the departmental studies triangle or vice versa.

The culmination of each of the triangular areas is an in-depth study built upon the preceding S- and G-vector components, and this is maintained at a more advanced level than the foundation courses. The terminal event in the general studies program usually centers on man and is a problem-oriented treatment of a single current topic using the framework of a seminar or individual study. For the departmental studies triangle, the termination of the S-vector is the more conventional senior research project and its final written paper. The quality of both of these more specialized events is dependent upon the cumulative support of G- and S-vectors within their respective triangular structures; however, interstructural crossover for the senior level projects is relatively uncommon.

The dual triangular plan is illustrated by the recent Hamline University program, having three essential parts.

(A) Skills. Proficiency in the fundamental aspects of English, foreign language, and physical education are established by examination, and are no longer viewed as primary teaching aspects of general education.

(B) Major Concentration. A departmental or interdisciplinary major composed of a specific number of introductory and advanced courses is required. The final portion of the major is an independent project followed by a comprehensive departmental examination.

(C) Generalized Study. In addition to the departmental major the student chooses a generalized study centered on a culture area, issue, or combination culture-issue study. (A fourth unified option is allowed.) The selected study must include a total of eight courses directly related to it; and the point of culmination is an independent project requiring a synthetic assembly and summation of the total general study.

The similarity to the older Columbia plan is only a superficial one, for the Hamline program assumes the same direction and structure to apply to the individualized plan for the student's general study as to his major study. The measure of effectiveness for the integrative approach in both areas is delayed until the time of the student's final independent projects.

One consequence of this structural form of curricular organization is that the student and teacher are fully conscious of the separation of general from departmental studies and that this isolation exists at almost all levels of the progression within each triangle. A contrasting strength of the plan

is the insertion of the vertical-horizontal tension as an integral part of general education itself, a missing feature of the simple linear vector models.

A third nonlinear model having increasing importance now is based more upon the student's learning processes than upon curricular arrangements. As has been expressed by Snow, no given subject fields can be specifically identified with liberal education while others are excluded.[9] Generalization depends more upon the process function in education than upon knowledge data. Therefore, the shift is from a discipline-centered structure toward a learner-centered one at the college level.

An early form of the model has been used for a number of years at Antioch College; however, newer programs are exemplified by those of Ottawa University and the University of Redlands. For the former, each student's contract has its own structure, but must include credits in general education seminars, electives, and depth studies. The seminars have changing content and are issue or problem centered, while the depth study is not confined to the conventional departmental major. The contract plan at Johnson College of the University of Redlands includes several student-identified areas of learning.

(A) Specialization directed toward a professional goal.

(B) Substantive problem-centered areas of inquiry.

(C) Mastery of methodologies chosen by the student.

(D) General and cross-cultural experiences.

(E) Mastery of an on-going physical activity or sport.

From a theoretical perspective, a new relationship of the educational process to its form becomes necessary if liberal learning is to be effective. The actual learning process is influenced by many variables including:

(a) the student with varying skills, effort, genetic make-up;
(b) the multiple curricula with very different goals and structures;,
(c) the techniques and tools of teaching;
(d) the environmental influences at the several levels of social interaction.

Any formulation of educational objectives is faced with the known complexity of the mental ability factors themselves which can determine to a great extent the outcome of the process. The analysis by Guilford of the matter of intelligence factors alone suggests that far more flexibility must be built into the organizational side of higher education as process.[10]

The various subject fields impinge upon the life and experiences of the student in a number of ways; and, as the student reacts as a learner, several facets of a particular field enter his directional response: (a) the structure of the discipline; (b) the factual basis of its structure; (c) unification and diversity of broad concepts in the discipline; (d) relevance of the discipline to man and his cultures; and (e) the likenesses and differences among subject fields. Whatever the pre-requisite tools and skills necessary for progress, the goal of the educational process in this way

assumes the prime function; however, that goal itself will be multifaceted, including: (a) a search for intelligibility; (b) a grasp of information production and movement; (c) a sensitivity toward and awareness of the dual operation of the human mind in both its analytic and emotive-intuitive functions; and (d) a series of value-based commitments in order that the individual can act within a social system.[11]

This re-direction of the educational focus toward the person rather than the field is derivative from the writings of Langer, Bruner, and McLuhan.[12] One consequence of this shift is that much less attention is directed at formal cross-disciplinary courses as such. In place of this, increased use of the subject specialties (though in drastically re-structured forms) becomes the pathway for reaching the educational goals. Thus, the need for particular arbitrary or artificial requirements in general studies disappears, and these are replaced by individualized course schedules for each student, consistent with the goals but operating within the available specialties. In one way the aims of higher education like those outlined by Chickering become the collegiate equivalent of altered behavioral objectives: developing autonomy, integrity, competence, and purpose; management of emotions and interpersonal relationships; and the ultimate emergence of personal identity.[13]

Although retaining both a vectorial and progressional character, the curricular structure in the system of individual advisement is not describable by any simple linear alignment of vectors as in Figure 2-1. Rather, a suitable analytical diagram must give greater attention to the ordering of specialty fields in relation to each other and to the directional feature originating with the learner. One suggested representation is shown in Figure 2-5; and, for the sake of brevity, this can be called the rotating disk model.

Vectorial processes are very much a part of this pattern, although the interaction of the directional components is no longer described in Cartesian coordinates. The radial vector (R) moves out toward a continuously expanding field content, incorporating the idea of an increasing diversity of knowledge exposure along with progression. In addition to R there is a second vectorial component (C) moving normal to the radial vector within the circular arc segments, expressing interdisciplinary comparisons and crossovers as a part of the learning process. As a polar coordinate system for the learner-discipline multiple interface, the representational surface depicts the two-directional nature of that process: the polar vector (R) for the outward translational motion through the fields; and the axial vector (C) for the rotational movement both within and across fields. This curvilinear coordinate system preserves the two-fold vectorial concept of the simple linear models; however, the new generalization vector (c) is now one of continuously changing magnitude and changing direction. (In this sense the vector (C) is more accurately described by the physical construct of the tensor; however, such a refinement will not be introduced here in order to retain continuity and simplicity among the contrasting models.)

Certain features of the rotating disk model should be noted. The axial vector (C) can operate at all levels of outward movement from the origin and its length varies from one student to another as well as from one field to another. Likewise, the length of the C-vector relative to vector R is variable, although in liberal arts institutions the sum of the several C-vectors in a given schedule still exceeds the length of the field vector (R). In this model the distinction between related departmental and general studies

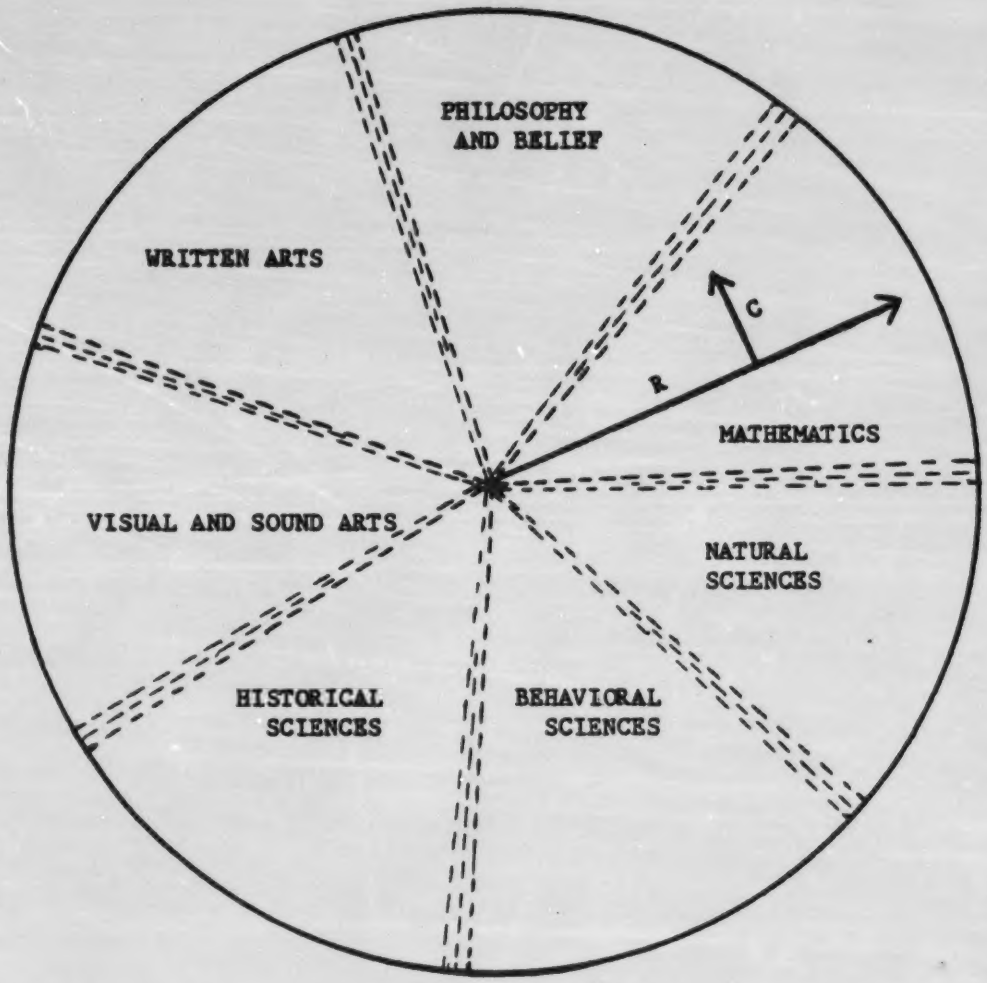


Figure 2-5. Disk model, process oriented

contributions to the total C-vector becomes unnecessary; and each component contributes to that sum without restrictions upon the size which each separate part must have. Thus, how far afield the student extends his C-vectors varies with the advisement. One clear advantage of the model is its inclusion of the shaded wedges representing the overlap of subject fields. With this arrangement the angular locus for the polar vector (R) can be oriented through an interdisciplinary specialization or major and then the axial vector (C) extends into the more narrowly specialized portions of the adjacent subject fields. Also, this emphasizes the need for careful planning of interdisciplinary majors to include a clear goal-directed progression for vector R, and not a major made up of a simple packaging together of lower level departmental courses drawn from related subject fields. The better planned ecology and environmental sciences majors illustrate the truly interdisciplinary fields consistent with the rotating disk model.

By eliminating all artificial specifications upon the particular areas into which the C-vector must enter, there is the likelihood that the student's collegiate experiences will not touch as many subject fields as in the triangular model. However, the explicit separation of general studies from departmental studies disappears, and the possibility of extending the C-vector into other broad subject fields at any level throughout the progression along the R-vector does exist in the rotating disk model. Because the length of the arc continually increases as R increases, it is obvious that most long range interfield crossing will still be confined to the lower steps of the progression. The wedge of the major field should convey the concept of a continually expanding area for the subject field itself, rather than the perspective of a narrowing specialization along the outward movement of R. This facet of the disk model is closer to the reality of growth in all knowledge areas, for in the initial stages of study the individual hardly perceives the vastness of the subject field and only at more advanced levels does the dimension of scope enter the consciousness. At the higher stages of the progression along R, the individual decision is made to restrict the length of the axial vector C in order to keep the time frame for collegiate studies manageable; however, in this view the decision for decreased generalization (or increased specialization) begins with the learner and is not one imposed prematurely by the subject field requirements.

Consistent with the student-centered orientation of programs for liberal learning is the very comprehensive definition of general education proposed by Smith.[14] He operationally specifies general education as "a set of experiences and opportunities for learning that tend to optimize simultaneously the breadth, integration, and fruitfulness of an individual's knowledge, experiences, emotions, motives and related mental phenomena within the limits and circumstances provided by his own intellectual and developmental potential, the surrounding society, and the non-human environment."

The potential relationship of social organization theory to such a learner-centered program has been noted by Pierce.[15] The fundamental structure is one of decentralized but flexible authority systems with individualized learning and instructional planning. The first appearance is one of educational improvisation, yet the sequential connections between planning and methodology which characterize the disciplines themselves are retained without much alteration. The learning process becomes a social activity in the technical sense; and it requires a new level of responsibility by the student in the identification of suitable goals and in the final social rewards,

4,

if behavioral change is to be expected. However, the underlying assumption that organizational structure must coincide with curriculum format does not fit the current realities of undergraduate liberal education. At the present time, the nearest matching is found in the student contract system, although that system is operated on student selection of an individualized program of study from a curricular array constructed largely by the faculty of the disciplines. Thus, the ordered specialization vector remains an imposed influence upon the student's learning experiences, and the gain of structural flexibility in the generalization vectors cannot hide this condition.

At this point certain summary statements are needed concerning the concept of the resultant in the several vector models considered thus far. Of course, the physical meaning of the term, resultant, still implies a total force as a summation of component forces and that sum represents a net magnitude operating directionally in coordinate space. However, even in the simplest linear models for vectorial alignments shown in Figures 2-1 and 2-2 the patterns of the resultants are by no means equivalent. For the parallel or antiparallel orientations, the resultant differs from its component G and S vectors only in its magnitude; and, as a directed force in space, the final resultant in the curriculum retains the vertical character of the specialization vectors. This can be contrasted with the situation for the S and G vectors oriented at right angles (and within the triangular model as well) in which the resultant differs from its component parts in both its magnitude and direction. In these instances the uniqueness required of the resultant is the same condition imposed by the area of union in the Venn diagram for liberal education (Figure 1-3). Some characteristics representative of such a curricular resultant are: (a) the continuous reconstruction of specific human experiences or phenomena in fundamental conceptual terms; (b) reality is viewed as necessitating relation rather than isolation of entities; (c) the comprehensive human experience can never obliterate or minimize the selfhood of the individual; and (d) valid creativity and synthesis is grounded in intensive complementary knowledge as well as in free inquiry.

The rotating disk model (Figure 2-5) not only shows the resultant of the G and S interaction being a fully unique total force but also raises the possibility of that force having a changing direction throughout the progression. Thus, liberal education as process is represented by a dynamic model with respect to the resultant, even though its parts are fixed within and across the disciplinary segments.

There are certain similarities between the rotating disk model and the circular model for knowledge structure proposed by Kenneth Boulding.[16] In the latter the fundamental aspects of the subject fields occupy the central core and the areas of newly discovered knowledge lie along the outer perimeter. The general features of this arrangement are shown in Figure 2-6 in which wedge-shaped segments designating the usual disciplinary fields have no restrictions upon their order of placement. As a model for knowledge structure itself, this form seems to offer no advantages over the Venn diagrams. However, one interesting feature of the Boulding view is that the portion of the total structure available and comprehensible to the individual learner appears as an irregular amoeba-like form superimposed upon the concentric circles. In one sense such a system implies the dynamics of knowledge acquisition by the individual with the analogy of the constantly changing shape of the growing amoeba. Weaknesses of the model are the assumptions of the "com-

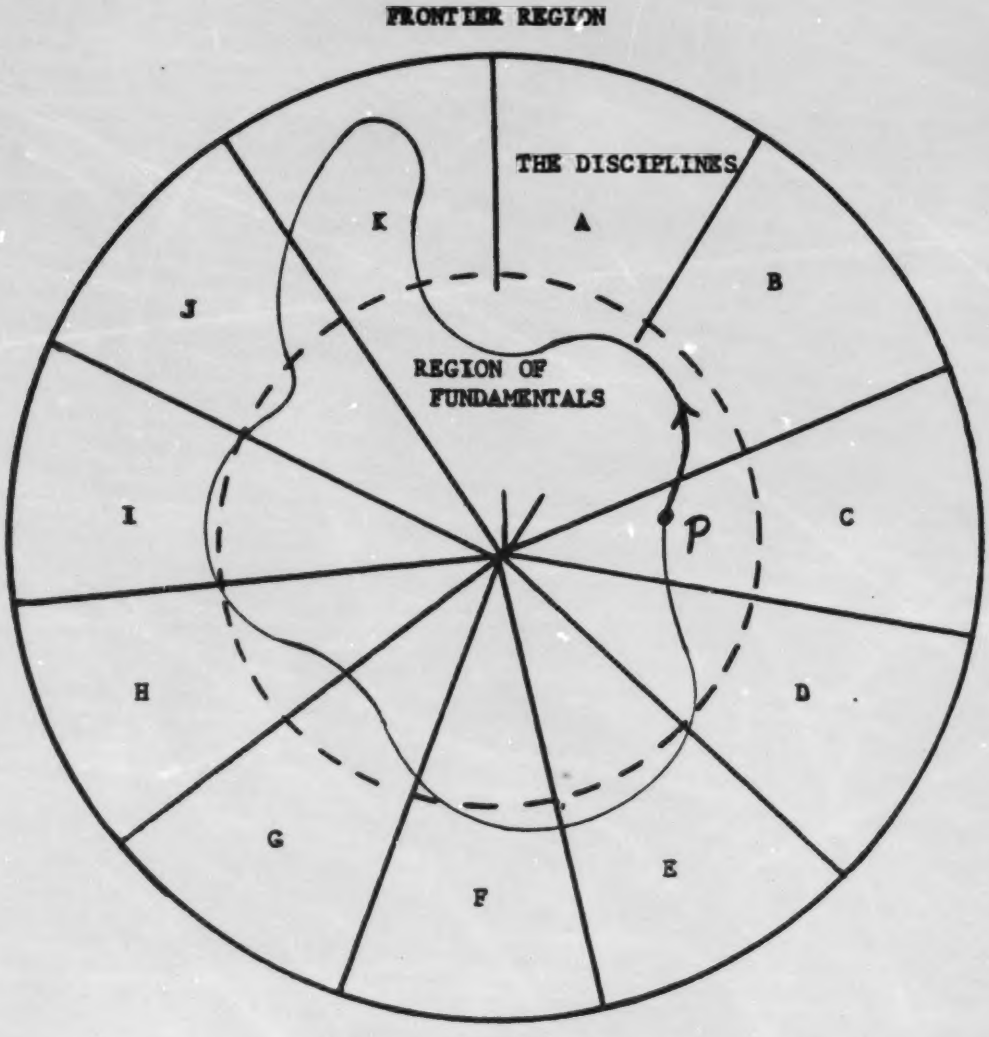


Figure 2-6. Boulding's view of knowledge structure

mon core" of formal curricular elements and the depiction of new knowledge evolving primarily at the frontiers of particular disciplines. In recent historical periods major break-throughs in knowledge have tended to arise from areas having no firm connection to the traditional disciplines; and, after discovery, the new concepts then re-shape the older subject fields or else produce altogether new specialties.

A fundamenal difference between the rotating disk model and the Boulding diagram is that the former is a mathematically based construct involving interacting vectors in polar coordinate space whereas Figure 2-6 is a scalar pattern having an assumed radial time function. Thus, a ciruclar model of this form is not a vectorial one but can be related to the composite scalar-vector diagrams of the type illustrated by Figure 2-3. The circular form for knowledge structure does place appropriate emphasis upon the mobile aspect of learning as process, and human curiosity serves as one stimulant to the fluidity of that process. Curiosity when coupled with imagination can lead to cognitive acts in which our mental images and ideas are synthesized from both the present stimuli and recalled past experiences of learning. Image-making activities are as much a part of the cohesive processes of general education as are the creative perceptions arising at the frontier regions of the purely disciplinary fields. Boulding has referred to these image-making actions as creating an "organized fantasy about the real world", being impelled by internalized mechanisms for error identification and error correction.

Since the Boulding diagram is primarily a representation of the curriculum from the viewpoint of the structure of knowledge, it is subject-oriented rather than process-oriented. One way in which this orientation can be modified conceptually is to view the total curriculum disk as a field of force in which the learner moves as a point (P) along the perimeter of the amoebic curve. Thus, the area encompassed by the cyclic locus of point (P) becomes a vector field within the knowledge plane, and the circumscribed area serves as a measure of the impact of the total curriculum upon the individual student. Mathematically, the area of the enclosed force field can be evaluated with Stoke's theorem and is equivalent to the line integral for the movement of point (P) in the counterclockwise direction.[17] The physical analog of this concept is that the enclosed area represents the work done in moving point (P) around the perimeter of the amoebic curve. Therefore, that confined area is a measure of the fraction of the total curricular force field with which the learner interacts.

If we use a "structure-of-knowledge" approach as the basis for disciplinary curricular organization, it is important to recognize that we are thereby isolating and manipulating only a portion of the student's total learning field extant for a particular interval of time. That total knowledge field can be roughly subdivided into knowledge derived from casual or superficial interaction with a variety of day-by-day environmental stimuli and that from systematic in-depth learning experiences which characterize the organized instructural programs of the schools and colleges. For the latter, we exercise some form of structural control over the learning processes upon the assumption that some management of the learning environment is necessary in order for lasting mental growth and modification of behaviour to occur. However, even within that limited portion of knowledge which we may designate as systematic several non-equivalent cognitive dimensional elements exist; and the threefold classification of Foshay[18] is a useful adjunctive device for examining structural models like that of Boulding.

A. Techniques. These are the fundamental skills for doing certain tasks; i.e. learning vocabulary and grammar in a language, manual skills in the operation of machinery, instruments, or programming a computer. The requisite training is directed toward high accuracy with the speed which accompanies repetition and conditioned behavior. Explanations dealing with "why" are minimal compared to "how"; and the importance of sequential operations is paramount in complex task systems, as exemplified by the operation of a spacecraft.

B. Factual Knowledge. Included here are the sum of all items which we would commonly term information, both descriptive and numerical, which are collected and stored. Because of the limitations on the human mind with respect to retention and recall, our educational plans in this area now concentrate upon those matters of organization, storage, and access to factual knowledge as a literal search for known information. As with techniques, the time variable makes us cautions. Thus, in dealing with factual bases for problem solving we fear that the information is unknown, unreliable, or out of date, so that the rapid communication and processing of the "new" fact-data becomes as essential as its appraisal.

C. Origins of Knowledge and Knowledge Processes. The epistemological matters of possible modes for knowing, generalizing, and theorizing fall into this class. These include hypothesis formulation and testing, the limitations within a given methodology, reasoning by induction and deduction, quantifying and deriving conceptual models, as well as the more intuitive elements we associate with creativity. It is this dimension of knowledge which we trace to the distinctive foundations of the various subject fields; and, although the rate of change here is less than in A and B, the process elements in methodology show considerable alteration and development from one generation of scholars to the next.

In formulating an educational model derived from a structure-of-knowledge viewpoint it is likely that all three classes of knowledge listed above are incorporated, at least by implication. However, a higher weight is usually given to the origins-process elements at the college level, and since these are clearly directional in shaping the form and content of the disciplines, such elements can be accurately described as vectorial. On the other hand, the stored factual knowledge or data items remain as the components of a scalar field (having magnitudes only) until such time as that information is used to generate a larger unity, a rule of correspondence, or a sorted output through associations between vectorial factors.

Even though the net relationships between the specialization and generalization vectors might be depicted by some simple linear combination, the contributing parts to generalization may require a higher order of dimensionality (greater than two dimensions) as well as some nonlinear curve or surface to describe the functional connections among the parts. This situation is well illustrated by the origins-process elements making up the general education segment of the Harvard undergraduate curriculum plan of 1978-79.[19] The major divisions of the core curriculum in that plan include courses within the following categories.

A. Literature, Fine Arts or Music, and Contexts of Culture.

B. Historical Processes and Perspective, and Historical Orientation to the Present.

C. Social and Philosophical Analysis.

D. Science and Mathematics.

E. Foreign Languages and Cultures.

Within the detailed descriptions of the types of courses suitable for each division above, one can readily identify a minimal set of three vectorial elements operating and shaping student learning in each area, namely,

(1) attitudinal (appreciative and empathetic dimension),
(2) analytical (problem treatment),
(3) expositional (writing and symbolic or mathematical manipulation).

Obviously, in any given division one of the three elements may assume a greater importance than another, as would be the case for the role of the attitudinal vector in history, literature, and the fine arts. Yet one must not overlook a significant even though secondary effect of the other two vectors as determinants functioning in these same areas.

One set of relationships among these three fundamental vectors can be illustrated in the Harvard core requirement for the history area. The core courses are grouped into the two categories: (a) the historical examination of events, social institutions and issues shaping the modern world; and (b) the historical process and perspective on developments, issues and conflicts from pre-modern times. As a starting point in understanding the changes anticipated in student learning about the global discipline of history, it is helpful to review possible interactions between the three vectors taken two-at-a-time. That is, the dimensionality will be initially reduced to two with a set of x vs. y graphs in order to achieve a greater degree of visual clarity; and these are given in Figure 2-7.

If the expositional vector includes both writing and mathematical skills, then a growth curve for the analytical vector vs. expositional vector should show a proportionate (or linear) increase as the student progresses. Likewise, in the optimistic view the growth curve for the attitudinal vs. analytical vector would be expected to exhibit an increasing though nonlinear trend. The reason for the latter expectation is that in earlier stages the development of analytical ability may be more rapid than observed changes in the attitudinal vector; however, as the analytical capability becomes more highly developed, the impact upon attitudinal elements is more pronounced and the attitudinal vector will rise at a more rapidly increasing rate. On the other hand, the growth in the expositional elements alone would not be expected to produce any profound attitudinal changes toward the goals for the student in history; and thus the attitudinal vs. expositional vector plot would be a nearly horizontal line of low slope. Obviously, for each of these two-dimensional growth curves, a given vector does not begin at the origin; and within history or any other core area the growth cannot continue indefinitely so that each curve implies some confinement of its length.

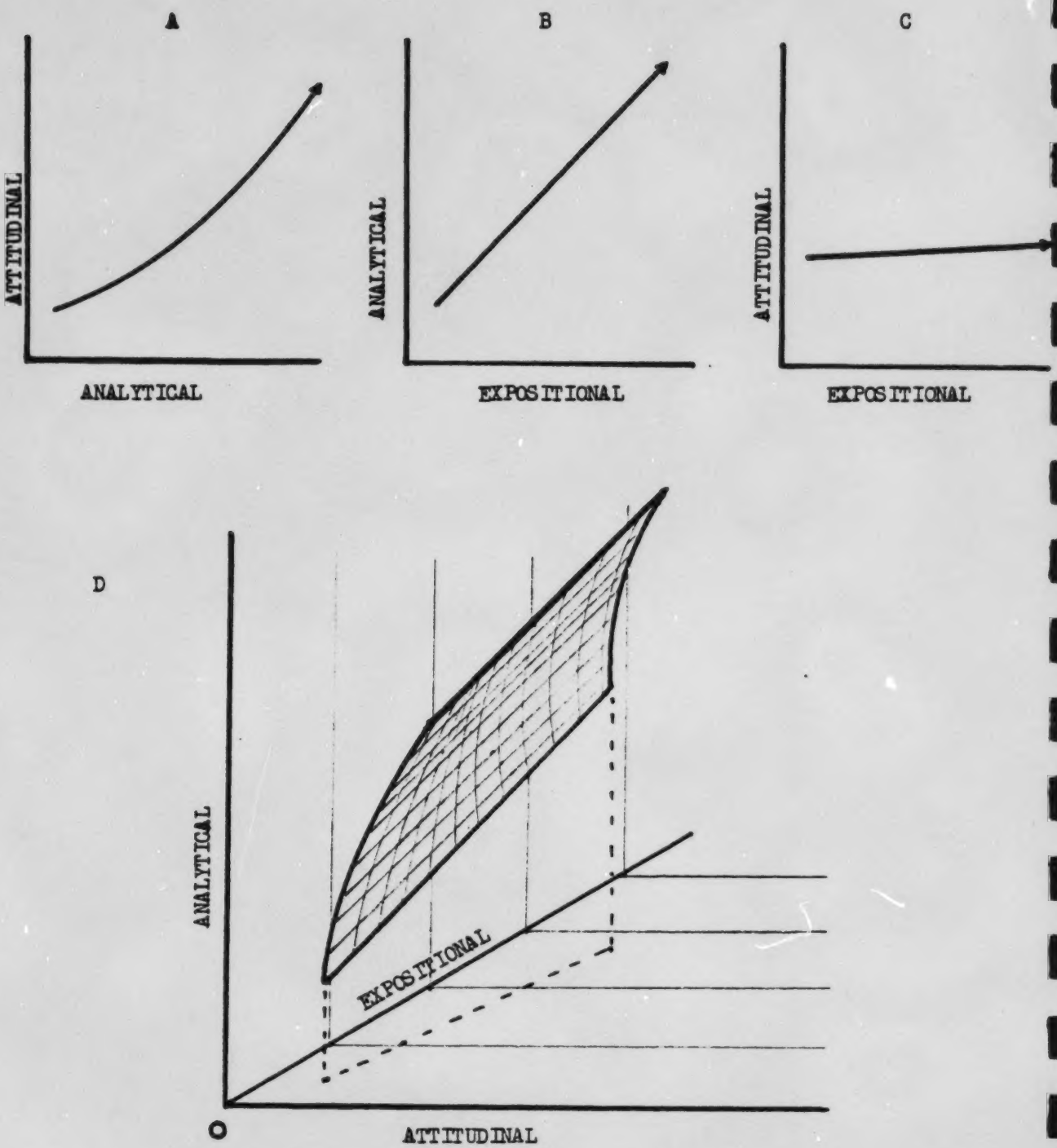


Figure 2-7. Planar projections (A, B, C) and composite surface (D) for vectorial determinants in the Harvard core requirement in History

For any particular growth curve we may draw, there will be limiting phenomena regulating that long term process which will correspond to a condition of leveling-off for the curve. The real growth function might be more accurately described mathematically by a sigmoidal function in the two variables with its implied asymptotic limits rather than by the simpler exponential curve for attitudinal vs. analytical plot and the linear functions shown in Figure 2-7. However, our sacrifice of mathematical exactness in this instance is accompanied by an increase in visual clarity when considering the three dimensional surface for analytical, attitudinal and expositional variables combined as a composite growth pattern for general education.

The introduction of visual models like those in Figure 2-7 illustrate how our understanding of the underlying form and intent of the generalization components within the newer Harvard curriculum can be extended. A superficial reading of the list of requirements has led some writers to erroneously conclude that the plan is merely a revival of a very structured area distribution format for liberal education.[20] By contrast, an analytical description with even a very simplified model leads one to quite different conclusions. As the reader will recall from the discussions early in this monograph, the area distribution plan assumes that the accumulation of a specified number of credits outside of the major and its closely associated fields constitutes the totality of the general education block. Thus, such general requirements are a series of independent quantities governed by a simple additivity rule when they are combined to yield a particular net sum of credits in general studies. Obviously, the concepts depicted by the more complex functions in Figure 2-7 cannot be reduced to a single linear sum as a composite description of the process elements included in the three vectors.

From the set of two-dimensional projections of pairwise relationships among the three vectors, it becomes possible to construct the final three-dimensional plot shown in Figure 2-7. In effect the surface formed here is like a curved and tilted sheet of paper with the curvature arising from the expected nonlinear trend between the attitudinal and analytical vectors. If we wished to use numerical data to measure incremental growth in the three vectors, then the mathematical function for the surface could be used for quantitative predictions. It would be anticipated that a similar graphic surface should describe the growth function for the three vectors within the core requirement in Social and Philosophical Analysis as well, even though the weighting factors for each of the vectors will differ from those relating to the history requirement.

Therefore, as one resolves the learning field into its separate though multiple variables shaping several of the learning processes essential to liberal education, the dimensionality increases and nonlinear relationships between vectorial components may arise. However, visual models of useful explanatory simplicity can still be designed for the representation of important aspects of these more complex systems. The dimensionality of our model defines the number of variables being examined for their connective relationships; and what we choose to include in a given graph is determined in part by our ability to distinguish and interpret trends among the quantities examined. Likewise, judgements concerning the appropriate dimensionality to be used in the visual model will reflect how one ranks the various interrelated factors in a hierarchy of n-dimensions. Visualizable patterns which may appear to be

initially naive can still communicate in an elementary way some meaningful information about the vectorial variables interacting within the collegiate learning environment and shaped by student and teacher actions.

Chapter III

MATRIX MODEL FOR CURRICULUM ORGANIZATION

One of the critical properties of the rotating disk model is that of the sequence for placement of the subject fields within the disk itself. As the fields of knowledge are subdivided further into the usual tagged disciplines and departments, the problem of ordering becomes vastly more complex. Yet, if the interdisciplinary areas are to be identified, it is necessary to give special attention to the fine structure of inclusion-exclusion phenomena between adjacent fields. Such a detailed treatment can be accomplished with the aid of Venn diagrams; however, when applied to the usual subject labels, this technique soon demonstrates that all of the implied contact regions between related fields cannot be fitted into a circular model. Only when the subject areas are described in the broadest terms is it possible to construct a comprehensive rotating disk form. A partial resolution of the geometric problem might be to use a spiral cone model; however, this form will not be explored here.

An alternate approach to representation of the vectorial interactions in a more refined space framework is to introduce the mathematical construct of the matrix. Matrix theory has been extremely helpful in applied sociology and economics, as well as in the better known examples in quantum mechanics, mass spectrometry, and genetics. Clearly, it is its predictive function and its ability to handle complex systems of quantities which relate the matrix to problems of curriculum organization. The uses of matrices in this section will be primarily qualitative and neither mathematically rigorous nor complete. The intention here is to demonstrate only the potential of the matrix as an additional model for program analysis in liberal education.

One initial assumption will be required, namely that the major curricular ingredients in whatever form are to be drawn from the disciplines themselves. This is the essential contention of Phenix when he states that knowledge in its entirety and in its perceived structural forms should originate with the disciplines.[1] This is not to say that curriculum design depends only on specific subject matter courses and thus is to be knowledge or fact centered. Rather, it is a minimal statement of the sources for easily identifiable units of content, methodology, and process in collegiate studies.

The concept of the vector is an integral part of the theory of matrices; however, as a mathematical term it can be used to designate an ordered set of quantities as well as the physical idea of a directed force having positional coordinates in space. In the first usage vectors are elements of an algebraic system governed by known operational principles without concern for their identification as particular types of quantities. For the purpose intended herein, the usual physical interpretation relating to a total vector for a force having both direction and magnitude will be retained. On the other hand, those circumstances in which a total vector is broken down into its component parts will require only the simpler view of an ordered set. Four fine introductory sources on matrix theory and notation may be consulted by the reader for added background.[2]

Some Fundamental Concepts

We can begin with the assumption that the subject discipline is the basic academic unit identified with specialization of knowledge, acting vertically in the progression. The discipline (S) has a series of vectorial parts in its total structure which are arranged in a sequence, whether these be courses, tools, skills, concepts, etc., contributing to the sum. Thus, each total S-vector in the curriculum can be separated, as written in Figure 3-1. Each discipline is simply numbered as S_1, S_2, S_3,...S_n; and binary subscripts are required to identify each component quantity (a) for the discipline to which it belongs and the sequential position within that discipline. Of course, an a_{21} is not necessarily equivalent to an a_{22}, etc.; and a given a_{mn} might be a zero entry, so that different lengths for the total S-progressions are implied. In matrix notation the individual disciplines represented in Figure 3-1 would be called the column vectors, designating the vertical elements.

The second overall force, that of generalization, can again be assumed to be a vector (G) oriented away from specialization and, as a vector, made of a series of parts. However, in the simplest view these parts are not independent of the S-vectors, but are obtained from various contributed quantities from each of the disciplines. (Again, the a_{mn} quantities are not confined to courses and can be quite general ordered parts.) The horizontal G-vectors can now be written in terms of their components, as in Figure 3-2. The same subscript notation applies to the G-vectors as in Figure 3-1, and likewise there is no requirement that every a_{mn} must be a non-zero entry. This construction of the G-vectors from S-components is described by the term, row vector. Arranged in this way, it is clear that generalization vectors can be formed at any level along the progression in the specializations, and need not be confined to the introductory level of concepts or knowledge data. For curricula using integrated general education courses the number of entries in a given G_m-vector will be large. At the other extreme, the area distribution type of requirements will have only one or two a_{mn} terms contributing to a given G-vector, and the result will be more accurately described by a series of short column vectors.

For our purposes, we may now relate the S and G vectors with a matrix structure shown in Figure 3-3. The matrix (A) can be defined as an array of entries whose values are real and usually placed in a rectangular pattern of vector quantities. The row vectors and column vectors within the matrix are easily visible, and in relationship to our model the total matrix A becomes the composite curriculum framework. In the special case where m = n the rectangular array simplifies to a square matrix having a number of useful properties.

Another important structural part in the matrix is the main diagonal (D) which extends from the upper left corner to the lower right for the square matrix, including all entries between a_{11} and a_{mn}.

$$D_M = \text{diag.}\ (a_{11} \quad a_{22} \quad a_{33} \quad \ldots \quad a_{mn})$$

The sum of the elements on the main diagonal is called the trace of A.

$$\text{tr } A = (a_{11} + a_{22} + a_{33} + \ldots + a_{mn})$$

$$S_1 = \begin{bmatrix} a_{11} \\ a_{21} \\ a_{31} \\ \cdots \\ a_{m1} \end{bmatrix} \quad ; \quad S_2 = \begin{bmatrix} a_{12} \\ a_{22} \\ a_{32} \\ \cdots \\ a_{m2} \end{bmatrix} \quad ; \quad S_n = \begin{bmatrix} a_{1n} \\ a_{2n} \\ a_{3n} \\ \cdots \\ a_{mn} \end{bmatrix}$$

Figure 3-1. Column vectors

$$G_1 = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \end{bmatrix}$$

$$G_2 = \begin{bmatrix} a_{21} & a_{22} & \cdots & a_{2n} \end{bmatrix}$$

$$G_m = \begin{bmatrix} a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

Figure 3-2. Row vectors

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ a_{31} & a_{32} & \cdots & a_{3n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

Figure 3-3. Matrix

$$A = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ \cdots & \cdots & \cdots & \cdots & .. \\ a_{m1} & a_{m2} & a_{m3} & a_{m4} & a_{mn} \end{bmatrix}$$

Figure 3-4. Triangular matrix

An interesting property of the trace in a square matrix is that the magnitude of the sum is independent of the order of summation. Thus, if an interdisciplinary study is constructed as a progression along the main diagonal, the sequential arrangement of concepts and principles within it does not have to be the same as is used in the separate disciplines in order to obtain a coherent sum. In addition to the main diagonal, subdiagonals of matrix A can be identified, as well.

$$D_{S2} = \text{diag.} (a_{21} \quad a_{32} \quad a_{43} \quad \dots)$$

$$D_{S3} = \text{diag.} (a_{31} \quad a_{42} \quad a_{53} \quad \dots)$$

These suggest the construction of multilevel interdisciplinary studies of more limited scope, for example interterm projects.

For a square matrix in which every entry above the main diagonal has a zero value, the array degenerates to a lower triangular matrix in Figure 3-4. This derivative analogy extends to the curriculum plans represented by the paired triangles in Figure 2-4 and discussed earlier. A property of lower triangular matrices is that their algebraic sums and products yield another lower triangular matrix. Therefore, a total curriculum summed from component triangular structural parts (separate general studies and departmental studies triangles) will result in a total process which retains the triangularly distributive character for the G-S vectors.

Matrix theory also provides a redundancy limitation for the total matrix A. If any two row vectors or column vectors in the complete square matrix are identical, then the value of the determinant of that matrix is equal to zero. It follows from this fact that the effect of numerous repetitive elements appearing across several disciplines is highly detrimental to the total curriculum, and, conversely, if the matrix is to have its maximum scalar value, redundancy cannot occur.

The total matrix A can be partitioned into submatrices, if some of the rows or columns (or both) are deleted. This is illustrated by the examples in Figure 3-5. This feature of the matrix model is particularly adapted to curriculum planning, for by using patterns like A_{11} or A_{12}, broadly integrated cross-disciplinary major programs can be developed. Under these circumstances the major is built from related elements from several disciplines, but must still retain the directional character of a single column vector as well as the directive row vector. In other words it is a progression involving elements of similar importance and magnitude drawn from adjacent disciplines. This application of the submatrix should not be confused with that of the diagonals. The latter do not have the properties of a column vector in the sense of a vertically ordered vector and are essentially in-depth studies on a single issue or topic of a general nature. In actual practice many cross-disciplinary programs have concentrated heavily on lower level entries from the related disciplines; however, the potential submatrix can be formed from upper level elements by the exclusion of components from the lower row vectors. For example, broad field major programs fitting such a pattern would be international studies, regional cultural studies, or materials sciences.

The submatrix concept handles the traditional major-minor distribution as well. For this purpose, the submatrix contains two columns and the full comple-

$$A_{i1} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} ; \quad A_{i2} = \begin{bmatrix} a_{22} & a_{23} \\ a_{32} & a_{33} \\ \cdots & \cdots \\ a_{m2} & a_{m3} \end{bmatrix}$$

Figure 3-5. Submatrix

$$A_{i3} = \begin{bmatrix} a_{13} & 0 \\ a_{23} & 0 \\ a_{33} & a_{34} \\ \cdots & \cdots \\ a_{m3} & a_{m4} \end{bmatrix}$$

Figure 3-6. Submatrix for major-minor plan

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ment of row elements in each of two adjacent disciplines. The change would be that the student or advisor gives a zero value to a specific number of elements in one column. This is shown in Figure 3-6. Of course, the submatrix can be easily extended to the plan requiring a subject major and two minors, and, since the minors are constructed from lower entries in the adjacent disciplines, the single column vector in the major gives a dominant S-vector character to the total rectangular array. The submatrix is applied here only to the disciplines and to their elements as vectorial components. Therefore, the term should not be assigned to administrative associations of departments, such as social sciences or modern languages.

An additional point related to the submatrices is that if two have the same number of rows and columns, then they can be added to form a new total matrix and that addition is commutative. Thus, within the restrictions, a total curriculum would be constructed from submatrices of the same size and those elements from each submatrix would appear in the total sum. This becomes a different way of viewing the grouping of interdisciplinary majors in the context of the other separate disciplines making up a liberal arts program.

A value of the submatrix form can now be illustrated by applying it to the arrangement of the elements in the area distribution curriculum plan for the generalization components of liberal education. If the total generalization vector G at any level of the progression with respect to the disciplines can be assumed to be a simple vector sum of its parts, then a three level requirement can be represented by the following equations. (The G's are all unequal.)

$$a_{11} + a_{12} + a_{13} = G_1$$

$$a_{21} + a_{22} + a_{23} = G_2$$

$$a_{31} + a_{32} + a_{33} = G_3$$

However, each entry is separable into a scalar factor b (a weighting coefficient) and an explicit vector property x_i. For a given discipline, let x_1 be knowledge data, x_2 the methods, and x_3 the conceptual structure. The three linear equations in G become,

$$b_{11}x_1 + b_{12}x_2 + b_{13}x_3 = G_1$$

$$b_{21}x_1 + b_{22}x_2 + b_{23}x_3 = G_2$$

$$b_{31}x_1 + b_{32}x_2 + b_{33}x_3 = G_3$$

The matrices needed for the solution set are given in Figure 3-7, and these are used in the matrix multiplication form B•X=G. For the system written as B•X=G, one interpretation would be that the composite column vector X is being transformed into a new vector G by the operation of matrix B.

Without proceeding further with a formal proof, an important mathematical property applies to such systems of linear equations: if the positions of any

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} ; X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} ; G = \begin{bmatrix} G_1 \\ G_2 \\ G_3 \end{bmatrix} .$$

$$\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} G_1 \\ G_2 \\ G_3 \end{bmatrix}$$

Figure 3-7. Matrix multiplication as: $B \cdot X = G$

$$A_1 = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} ; \quad A_1^T = \begin{bmatrix} a_{11} & a_{21} \\ a_{12} & a_{22} \end{bmatrix}$$

Figure 3-8. Transpose

two equations in the original system are interchanged, the resulting system is equivalent to the original. For the matrix, the interchange of either row vectors or column vectors in B does not alter the solution set in X. The derivative predictions with respect to forces acting toward generalization in the area distribution requirements are as follows.

A. The sequence in which the a_{mn} vectors appear in the linear sum has no effect whatsoever on the resultant G-vector. In other words the order in which the student contacts each particular disciplinary element in his program is not critical.

B. Although none of the weighting factors (b) or the particular property vectors (x) would be expected to have identical effects on a given G-vector, interchanging the levels among sets of generalization requirements would not make any net change on the resultant vector.

C. Interchanges of the order and/or the levels at which generalization G-vectors are placed in the curriculum does not alter the impact (or magnitude) of the various properties of method, data, etc. upon the given G-vector.

Obviously, these conclusions apply only to the submatrix of the generalization vectors constructed from the discipline column vectors. Order of placement of elements within the specialization vector for a total curriculum is a completely separate consideration. However, if the total curriculum is partitioned into the two submatrices, G (generalization) and S (specialization), the relative importance of each can be expressed by assigned weighting coefficients as scalar factors g and s. Assuming that G and S are square, each submatrix will have a value for its trace as the linear sum of its diagonal elements; and the trace of the total curricular matrix (gG + sS), can be evaluated directly from the partitioned segments. Or, stated mathematically,

$$\text{tr}\,(gG + sS) = g\,\text{tr}\,G + s\,\text{tr}\,S\,.$$

The fundamental weakness of forming the generalization vector from a linear combination of elements obtained directly from the components of the specialization vectors has been discussed in the preceding section. Nevertheless, the additional characteristics of the matrix model suggest other ways to formulate the G-vectors.

If the functional role of generalization is to be introduced as a more nearly single level horizontal vector, the interdisciplinary crossing by a diagonal is not a suitable pattern. Another concept can be employed to restructure the G-vector, that of orthogonal vector quantities. In the literal sense the condition for orthogonality of vectors requires that a given set of linearly independent vectors be used to construct a new set of vectors whose members are mutually perpendicular. For our purposes, only the sum of G and S are involved. If these vectors have magnitudes expressed by the scalars, s and g, the statement of orthogonality of the vectors is: $s \cdot g = 0$. Thus, the zero value for the scalar product becomes an exclusion rule, one which removes from consideration all sets except those which are mutually perpendicular. With respect to G (total), orthogonality would be served by the following:

A. Perpendicularity of the G-vector to the discipline implies that specific

courses or their sequences are essentially single level, not multi-level.

B. Structural components of the G-vector are no longer segments taken from the S-vectors and re-arranged in various linear combinations. In other words the broad survey of factual knowledge from several related fields does not fulfill the requirements for generalization in this view.

C. Since the G-vector is restricted to a particular orientation in space and is a resultant from the new vector set used to achieve that orientation, the condition of linear independence necessitates that new entries and different conceptual insights go into the construction of the elements of generalization.

General education courses designed for the foundations concept in the triangular curriculum model discussed earlier would fit these new conditions of restraint and can be more accurately described by the term orthogonals. Although the idea of orthogonality can be extended to the matrix as a whole, the interpretive problem is considerably more complex and will not be undertaken here.

Another property of matrices, that of the transpose, relates to the problem of ordering of curricular elements. By definition the transpose of matrix A (Figure 3-3) is a new matrix A^T formed by interchanging the columns and rows of A. This re-arrangement can be applied to square submatrices, as well, and is shown in Figure 3-8. If the result is one where $A_1 = A_1^T$, then A_1 is called symetric. In general this condition will not be met in the total curriculum matrix A, since all elements within it are characteristic entries. The conclusion to be drawn is that the elements from generalization vectors (row vectors) cannot be substituted for specialization vectors (column vectors) in the construction of the disciplinary field emphasis without changing the final outcome. The same observation applies to the submatrix and serves as a cautionary note in planning the broadly based cross-disciplinary major programs. The latter cannot be made by using G-vectors in some specified order in the submatrix because the transpose would then become symmetric. The G-vector still would retain its same function in A_1^T without the simultaneous appearance of any element of specialization in the submatrix.

There is one sense in which the square submatrix can be thought to be symmetric even though composed of only unique entries. A given matrix A is called skew-symmetric if the transpose gives the result, $A = -A^T$. From matrix theory, it is known that any square submatrix A can be resolved into the sum of a symmetric matrix A_j and a skew-symmetric matrix A_k. This can be stated in symbols as follows:

$$A = A_j + A_k$$

where the two terms are evaluated by the operations

$$A_j = \frac{A + A^T}{2} \qquad \text{and} \qquad A_k = \frac{A - A^T}{2} .$$

Thus, it is not incorrect to infer that curricular submatrices do have inherent characteristics of symmetry for generalization elements; however, a second term contributes to the total submatrix and it is the term which makes the

total submatrix asymmetric with respect to interchange of the G and S vectors in its structure.

If the vectorial interpretation of generalization-specialization interaction as liberal learning is a reliable one, then the more sophisticated matrix model offers some helpful insights into possible relationships of the total structure provided by the model. A variety of different aspects of generalization are incorporated.

(A) Single-level general education (orthogonals) - using concepts, techniques, and facts, integrated horizontally.

(B) Multi-level diagonal studies - formed by broad themes which are cross-disciplinary in essential content. Examples of such studies are: crafts and cultures; symbolism and communication; time and space; and materials sciences.

(C) Upper-level submatrix major - constructed from advanced segments of the related disciplines. Examples are: Latin American studies; regional natural history; and human ecology.

(D) Departmental generalization - within the traditional disciplines the breadth function entering at any level where approproate (not restricted to the usual lower level cognate areas).

The diagonal studies in type (B) as well as the submatrix groupings in (C) above need not be confined to those combinations which represent any undergraduate major. For example, transdiscplinary clusters of courses which are equivalent in amount to minors have been developed at Cornell University,[3] and these have the identifying label of "concentrations". Included among these thematic areas are: Law and Society; Latin American Studies; Near Eastern Studies; European Studies; and African Studies. Particular courses incorporated in a given concentration are drawn from various departments or schools, thereby avoiding the creation of new departmental entities; and usually a given concentration includes four courses concerned with the cultural, social and philosophical dimensions of the theme. Thus, the concentration differs from the traditional minor in that it is not simply a subspecialty of a given major nor a cognate area supportive to a pre-professional field of study. An important function of the concentrations is the involvement of the pre-professional students in a unified segment of humanistic studies and, by administrative arrangements, to bring together faculty from different departments into the organization and development of those concentrations. In this way a general education component is moved beyond purely a breadth dimension toward a true integration of more advanced learning which is centered upon sufficiently broad themes not adequately encompassed by any single discipline.

Additional Applications To The Curriculum

The few illustrations of G and S vector relationships formulated with the aid of matrix properties suggest that the model has considerable analytical potential for the interpretation of education as process. The process oriented curriculum then becomes a time-independent comprehensive set of planned educational experiences stressing emergent and directional movement on an ever broadening scale. By shifting toward a model expressing the interdependence of essential vectorial forces, the fundamental process emphasis is loosened

from the old boundaries of the three to four year time frame for undergraduate education.

For one form of a curriculum structured in this manner, the term "competence-based curriculum" has been proposed by Bob Knott.[4] He has listed four essential focal points in such an empirical design for learning: (a) values identified with the institution; (b) a developmental scheme for assessing and promoting student growth; (c) an epistemological framework for creating meaningful knowledge; and (d) a single area or group of subject fields in which the student has moved toward an advanced level of expertise. It would be expected that all of these characteristics of the learning design should lead to modified student behavior which is measurable; however, the assumed rigidity of the time schedule in traditional liberal arts programs is no longer required by a competence-based curriculum.

Matrix models exhibit the potential for rescuing some areas of curriculum planning from the entrapping ambiguities of conventional language often used to discuss general education. As has been stated by Scigliano and Scigliano, verbal definitions of general education are usually sufficiently vague and non-operational that there is no meaningful way to deduce specific features for inclusion within a curriculum.[5] These writers have presented arguments for using the Delphi method for obtaining a convergence toward a local definition of general education and have emphasized that program structure and strategies for teaching must be consistent with such an adopted definition. However, the expanded view of generalization within various segments of the curriculum as suggested by items A through D above necessitates the addition of symbolic and mathematical language to such structural models for liberal arts curricula.

An existential approach to general education has been proposed by Stephen Bailey[6] in which the realities of an individual's adult living and lifelong learning are placed in three fundamental dimensions: (x) coping (to perform the day-to-day personal biological and social functions; (y) working (occupational activities for financial remuneration); and (z) the free self (the inner satisfactions, aesthetic responses, and moral-religious sphere). Rationalistic programs for general education have emphasized the development of the free self while minimizing or ignoring the coping dimension. On the other hand, the disciplinary majors have of necessity concentrated on the working dimension in stressing both the specialized and the general aspects of particular academic subject fields. The most obvious extension of the suggestions of Bailey to a visual model is to assign the three existential components to the axes of three-dimensional coordinate space as shown in Figure 3-9.

Within that defined space the individual's educational locus at a particular moment is a point P(x,y,z,) determined by the three component dimensions; and the path of educational development may then be viewed as an empirical curve formed by the vectorial point P moving in space with a continually shifting direction or alternately as the movement of a set of interdependent points, P_1, P_2, P_3, etc., through space to define a surface function. The visual model implies that the structural problem can be simplified in part by examining the two-dimensional projection of the composite mathematical function as one attempts to concentrate on specific curricular elements. For example, it is conceivable that a specific general education program might be designed so that the working (y) and free self (z) dimensions would show comparable or related rates of development with the result that the projection on the y-z plane might evolve

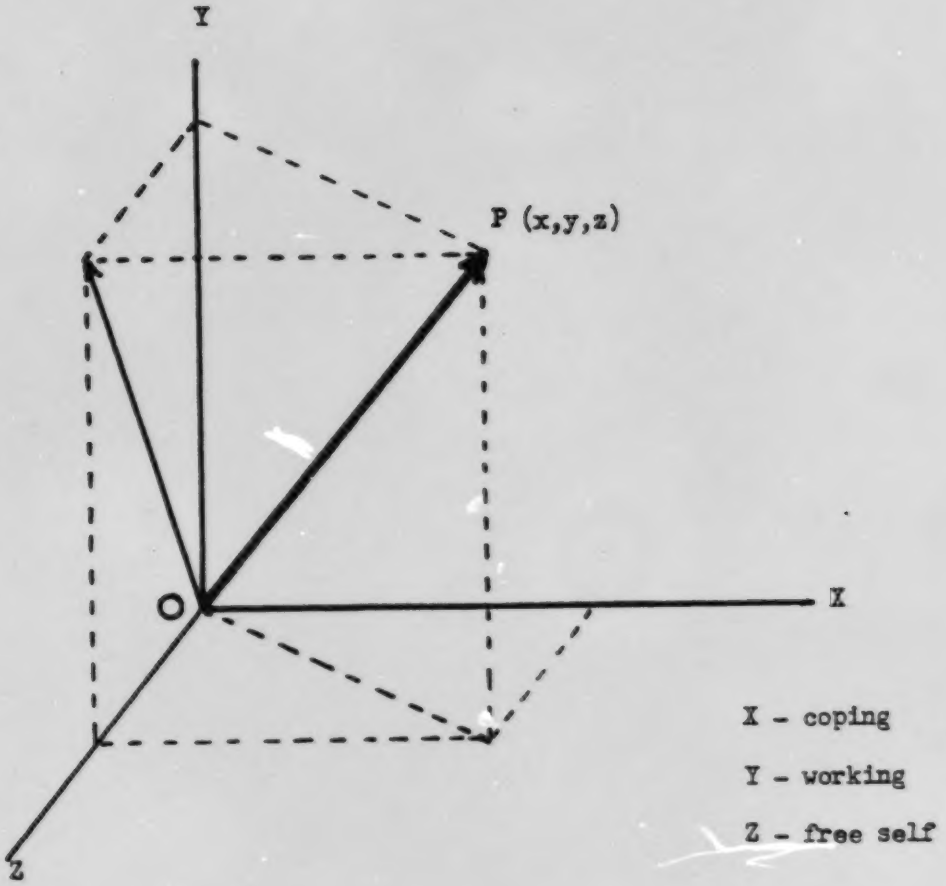


Figure 3-9. An existential view of the components for general education

a linear (as in Figure 3-9), rational, or exponential growth function. Thus the more complex planning problem can still be resolved into components of lower dimensionality for easier manipulation of the macro-problem itself.

A two-dimensional vector diagram used to represent external variables influencing program planning has been termed a cross-impact matrix by William Bergquist.[7] The composite impact of each parameter is given as an algebraic sign: positive, negative, or zero, with respect to existing or planned programs and each is placed within a square grid. Qualitative conclusions can then be formulated by visual inspection of the grid matrix in order to identify those clusters of program elements which are interdependent and to decide whether or not new programs will interact in a net positive or negative way with important existing programs. Although having very limited predictive utility, the cross-matrix technique provides a simple means for visualizing the interconnections among those elemental components which can modify program outcomes in long-range planning systems.

The various features of matrices considered up to this point have been fundamentally deterministic with respect to the elements selected for inclusion in a given matrix and their effect upon the structure of the curriculum as a whole. However, it should be noted that there are a number of potential applications of matrix theory to stimulus-response models for learning in which the basic treatment within a given model is probabilistic. For such S-R models for learning, the outcomes are the result of a sequence of stepwise choices arrived at by the chance selection of options at decision points along the learning path. Mathematical models of this type involving randomly determined outcomes are called <u>stochastic processes</u>; and several examples of S-R models derived from Markov chain diagrams have been reviewed in detail by Fred S. Roberts.[8] Such stochastic models for learning share a common assumed mechanism in that the learner samples (or contacts) a given stimulus which then elicits a specific response and that response is rewarded or punished as a mode for conditioning the pattern of behavior of the learner. Since all of the decisions by the learner are considered to be of a binary either-or type, the models are designated by Roberts as all-or-none with respect to the impact of the decisions upon the probabilistic outcomes for learning.

The assumed sequence of steps in S-R learning models are: (a) the initial state of conditioning before each trial; (b) the sampling of the given stimulus; (c) the response on each trial; (d) reinforcement by reward for the choice of a correct response; and (e) change of conditioning on the part of the learner by comparison to the initial state (a). On each trial, the learner begins by sampling or not sampling the stimulus with a probability of P_s for step (b) and an either-or response in step (c) with a probability of P_g. If the correct response is always rewarded, the probability for step (d) is unity; however, in some models this certainty is not assumed for (d) and another probability parameter, P_r, is introduced for the reinforcement step. Finally, if the learner becomes conditioned to the stimulus at the end of the trial, the likelihood of this happening is stated by a probability factor, P_c.

The basic sequence can be generalized to trials involving multiple stimuli by treating each stimulus as an independent element leading to the same either-or type of responses.[8] From a specific set of assumptions, anticipated values can be estimated for the various probability factors in the S-R sequence; and then the validity of these assumptions is determined by comparisons between

the predicted value of the parameters and the empirical pattern of responses for repeated trials with groups of students.

Probabilistic modelling techniques of this type can be extended to some aspects of problems related to choices made within curricular patterns, and a single example will suffice to demonstrate the power of such applications. Let us consider the case of a liberal arts curriculum having an area distribution pattern for general education like that in Figure 2-2 in which each student is required to take one science course of four credit hours during the freshman year. The student is allowed to freely elect a course from those available options offered by the three departments, biology, chemistry, and physics; and each science area has both conventional laboratory and non-laboratory (lecture-film-demonstration) courses open to all students. Within this framework let us now consider the question: what is the likelihood (probability) that the student will select a laboratory course in a given department if the choice is purely a random one made among the following courses?

Department	Lab (L)	Non-lab (N)
Biology (B)	General Zoology	Ecology
	General Biology	Natural History
	General Botany	
	Genetics	
	Human Physiology	
Chemistry (C)	Introduction to Chemistry	Chemistry and Society
	General Chemistry	Chemistry of Life
	Inorganic Chemistry	
Physics (P)	Survey of Physics	Energy and Society
	General Physics	Astronomy

The options for the student can be visualized using the tree diagram in Figure 3-10 and the probabilities for each path are included in the diagram. The latter are determined as follows: (a) for each step, the probability is the ratio: $\frac{\text{number of options in one class}}{\text{total options of all classes}}$; and (b) for the sequence in which the outcome of a succeeding step is determined by the distribution from the preceding one, the final probability is the product of the two contributing probabilities. Thus, in Figure 3-10 the initial random choice made by the student is to select one of the three science departments, B, C or P. The final composite probabilities for lab vs. non-lab choices are shown in the last column of the diagram.

One conclusion from the figure is that th students are most likely to select a conventional laboratory course in biology 2.5 times as often as the non-laboratory course in biology. Likewise, biology laboratory courses will be chosen 1.4 times as frequently as a physics course and 1.2 to 1.8 times as often as either of the chemistry options. The stochastic model suggests that among any set of equivalent credit courses the random choices by the student will tend to lead to a larger number enrolling in the biological sciences because of the larger number of departmental courses being open to the general student. On the other hand, any departures from the predicted distribution of the probabilistic model would indicate some non-random element was influencing the choices made by the students, and for this case definite causal factors should be identified.

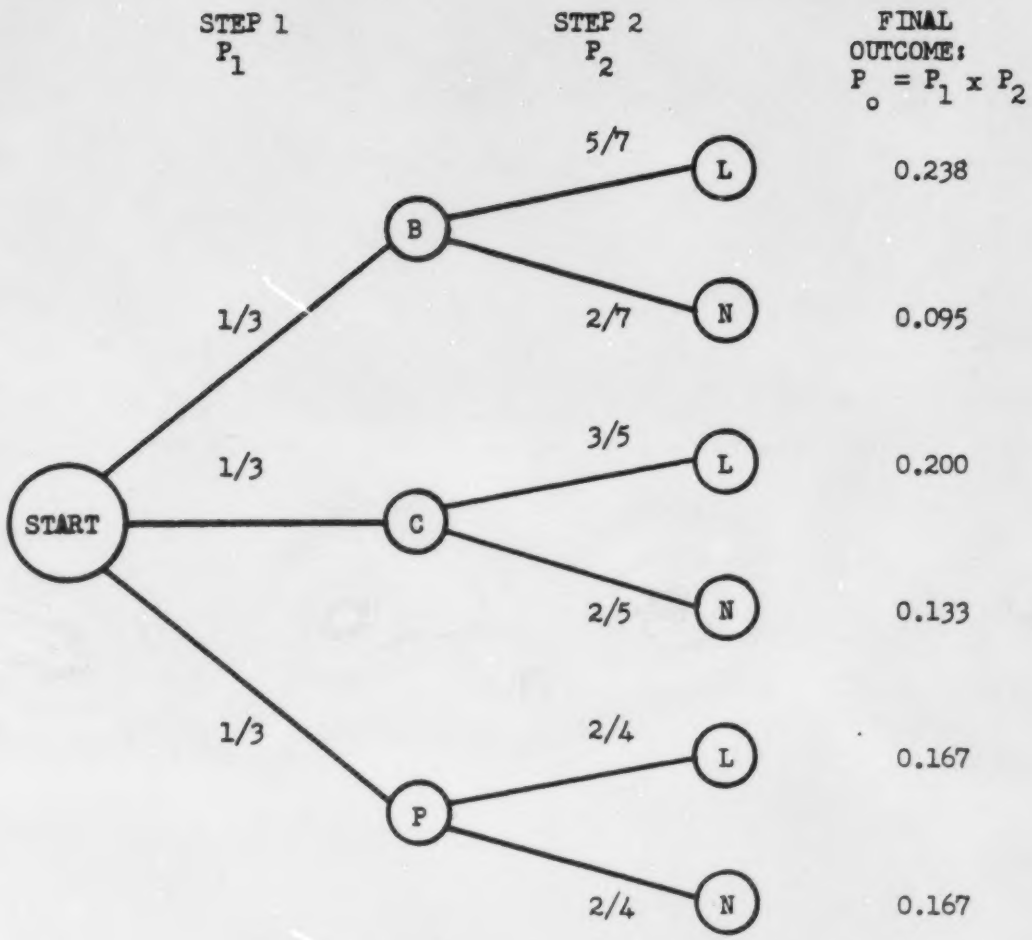


Figure 3-10. A stochastic process in an area distribution plan for the natural sciences

Applications of probabilistic models to S-R learning experiments as well as curriculum problems illustrate the importance of quantitative predictions when used in support of theoretical constructs in education. However, such models remain primarily descriptive of the behavior of the real systems they represent and the objective for these models is to accurately duplicate the behavior of those real systems. The failure of a given stochastic model even after extensive modification can direct the analyst to search for more specific determinants which operate in a non-random manner. Thus, the simulation of a given educational process uses a minimal set of variables necessary to duplicate the real system; and, although the generated hypothetical data for the model may be checked against empirical outcomes, those comparisons ultimately permit us to identify only the dominant variables showing parallel behavior in the model. For microscale simulative models of instructional modes, sufficient data may be generated to allow data treatment by acceptable statistical tools for the analysis of correlations, distributions, and multiple regressions.[9]

It is in the educational applications of stochastic regression models that matrix formulations are again useful. Both simple and general linear models for relating unknown predictors to a particular response variable can be stated as a matrix as well as an algebraic equation; and it is the matrix form which is advantageous in the manipulation of multiple parameter linear functions. The broad topic of statistical inferences drawn from general linear population models is beyond the scope of this monograph and the interested reader may wish to consult a more specialized source for additional information.[10]

Chapter IV

STRUCTURE WITHIN THE DISCIPLINES

In his analysis of the disciplines from the point of view of conceptual unity Jerome Bruner concluded that there are at least four defensible claims for using a structural approach to the teaching of a given subject area[1].

(A) Greater comprehension and depth awareness follow the understanding of fundamental principles.

(B) The specific situation or phenomenon can be recognized and understood within the context of the related general case (i.e. transfer of learning).

(C) Because of the limitations of the human mind, an essential role of organized knowledge is to minimize the need for memorization of great detail.

(D) The emphasis on general and basic principles has a feedback effect upon the arbitrary distinction between introductory and advanced knowledge in the field, tending to blur that separation.

Beyond the justification for an organizational scheme for learning and teaching of a particular subject field, these claims re-state the functional need for generalization as a basic force within the disciplines themselves. Although specialization remains the dominant vector in the discipline, generalization is essentially inseparable from it.

There are qualitative and quantitative distinctions between the curricula for particular subject fields in the liberal arts colleges and in the university degree programs. The most obvious difference is in the number of credits required in the major in the two types of institutions. However, there are more basic differences involved: the liberal arts departments place less value on a professional level of skills and specialization in sub-areas of the subject field; more study in cognate areas is encouraged or required; and the teaching of the discipline is directed toward its larger relationship to man and society. This modification of the disciplinary curricula, including to some degree breadth of knowledge skills as an essential part of the majors, reflects a greater value assigned to generalization in the liberal arts setting than usually is assumed in the university.

Because of the apparent operation of the vectorial forces of specialization and generalization both within the discipline and in the total liberal arts curriculum, the various analytical models reviewed previously can be extended to the structures of the disciplines as well. Here the approach will be one of examining representative examples rather than a comprehensive overview, and the formulations of the models will be outlined in quite general terms. Two widely divergent subject fields were selected to illustrate the application of models to disciplinary curricula, namely the visual arts and the natural sciences.

The Natural Sciences

The major programs in the physical and biological sciences as well as engineering fields have long been identified with rather clear sequencing of

courses and well defined requirements in supportive subject areas. Although organizational features of natural science curricula have undergone gradual changes in the past decade, the larger changes within the sciences have been in the subject content of the specialties operating under the traditional labels of zoology, chemistry, physics, etc.; and these changes have mirrored the rise and decline of sub-fields within the disciplines and an increased emphasis upon problem-oriented study necessitating greater cross-disciplinary contacts and greater generalization. For all of the natural sciences, the twentieth century has been a period of diversification of subject field content accompanying the rising conceptual and experimental sophistication. The tension between the practical and the theoretical has been as real as that between specialization and generalization in the total curriculum.

In his analysis of the nature and structure of science, James Robinson contends that the differences in the developmental processes used in the biological and physical sciences are not real and fundamental, but rather that the distinctions arise from the variation in emphases given to epistemological elements.[2] He proposes that an appropriate model for the organization of the thought processes in the sciences is a field continuum defined by the vector pair, induction and deduction, which additively combine in scientific theory. Component parts of the inductive element of theory are observational data, constructs, and conceptual schemes. The parts of the deductive element in the theory are principles, laws, hypotheses, and predicted facts; and in Robinson's view deduction has the larger sum. Thus, the ground for both the inductive and deductive vectors lies in the empirical observations of the sciences. For the biological sciences, the teleological and historical components make larger contributions to the deductive vector than is true for most of the physical sciences. The area of physics is exceptional in that the historical thread is effectively drawn through the study of motion and atomic structure from the time of the Greeks to the present century. However, Robinson bisects all of the process and structural segments (inquiry, data, rules of correspondence, constructs, theories, and verification procedures) into the contemporary and historical aspects in both the biological and physical sciences.

Natural science curricula are particularly adapted to interpretation by the matrix model because of their traditional emphasis upon ordered course segments, developmental constructs, and pre-requisite structures in cognate areas. However, in attempting to apply the matrix to what is truly a submatrix, the entries used must not be stated in terms of particular courses and facts but rather as specified concepts, skills, operations, and materialistic or mechanistic models which determine the composite structure. How these elements are distributed among specific courses is quite arbitrary and variable, and it is peripheral to the process concept in educational programs.

Instead of beginning with the individual sciences themselves, let us identify those elements of generalization upon which all of the sciences are heavily dependent and are held in common by both the biological and physical sciences. These can be used as the entries in the column vectors placed adjacent to the column vector of the major in assembling the total submatrix. Two broad supportive fields for all of the natural sciences have been mathematics and language study; however, the elements drawn from these fields must be stated in more general terms. In the liberal arts institutions it is rare for the cognate areas to give separate course content or emphasis for the particular benefit of the single group of science majors (or fine arts majors, etc.); therefore, the elements in the column vectors will be essentially the

same ones used in formulating an S-vector for the disciplinary major in mathematics and language study. Since these components are an incomplete set of ordered items obtained from the specific column vectors, the notation will need to be altered as follows: let s_2 be mathematical skills, s_3 English language items, s_4 computer language study, and s_5 foreign language.

Within the non-machine language areas

a_{4n} = fundamentals of form and usage in oral and written communication

a_{3n} = reading and interpretation of printed cultural language.

For the study of computers,

a_{4p} = machine languages and programming

a_{3p} = data processing, solving equations, and machine graphics.

Then, the column vectors for language study can be stated:

$$s_3 = \begin{bmatrix} a_{33} \\ \\ a_{43} \end{bmatrix} \quad ; \quad s_4 = \begin{bmatrix} a_{34} \\ \\ a_{44} \end{bmatrix} \quad ; \text{ and } s_5 = \begin{bmatrix} a_{35} \\ \\ a_{45} \end{bmatrix} .$$

It should be noted that all of the a_{mn} entries can be resolved into two quantities, $a_{mn} = b_{mn}\, x_i$, where b_{mn} is a weighting factor and x_i the fundamental vector quantity for the item. There is no implied assumption about the magnitude of b_{mn}, only that it can be positive or zero.

In general the number of entries in the column vector drawn from mathematics will be larger than from the languages, since the relationship of mathematics to the natural sciences is one of both manipulative skills and connective philosophy. A minimal set follows.

a_{42} = operational skills for algebraic systems

a_{32} = data treatment and design of experiments

a_{22} = formulation of mathematical models and their solutions (the calculus, differential equations, and approximations).

The column vector s_2 is shown in Figure 4-1, and again any a_{mn} can be separated into a product of a coefficient and the fundamental vector. The complete submatrix of generalization (g) is now given in Figure 4-1. Of course, a particular science area may assign a zero value to s_5 or to a given a_{mn}, and more entries may be placed in the s-column vector than shown, with a resulting change in the shape of the generalization submatrix.

Any formulation of the column vector for the major in the natural sciences must include those items which characterize the structure of undergraduate education in the broad areas of science while recognizing the variations in emphases among the areas. The problem is analogous to the search for <u>the</u> scientific

method, and the outcome must be representative of a plurality of procedures and practices. If we confine our attention to the physical and biological sciences, several elements held in common can be identified. The following list is not a comprehensive one.

(A) Minimal set of verifiable facts. In the early stages of science education the student contacts a limited quantity of empirical observations and/or experimental information which are fundamental to the subject field. This encounter with the knowledge data resources precedes any attempts for generalization, and this element can be considered to be the taxonomic material from which the given science is built. In general the facts revolve about descriptions of form and energy relationships in all of the biological and physical sciences.

(B) Epistemological foundations. The basic philosophical assumptions for the "how we know" aspect of the natural sciences are stated only in their simplest form in the introductory science courses. Although not usually given formal treatment later, the evolutionary character of the epistemology of science is made visible as the level of sophistication of argument and concept advance. In its most rudimentary form the emphasis is upon fundamentals of logic applied to objective observations and to experiments with controls.[3]

(C) Hypothesis formulation and testing. Throughout the curriculum in a given science, a succession of opportunities and practice in shaping hypotheses and the testing of these are incorporated into laboratory studies or thought experiments. In a simple form the method may be the examination of operational definitions.[4] Again, the process is a developmental one in which hypothesis refinement accompanies increased sensitivity in laboratory instruments or observational skill. Concomitant with hypothesis testing is instruction in the design of experiments, operational understanding of appropriate measurement instruments, and evaluation of the reliability of experimental data.

(D) Laws and generalized concepts. Through the detailed examination of known and limited variables, generally valid qualitative or quantitative laws become apparent. The observed regularity of the given function may require the introduction of a fully new concept (as that of a gravitational field of force from Newton's law of gravitation). Thus, from an educational viewpoint, the law and its derivative alteration of conceptualization for natural phenomena cannot be separated.

(E) Comprehensive explanations and theories. The broad and unifying explanation leads to a decidedly greater depth of understanding than is possible from the specific laws alone. It is in the studies of theory formulations for simplicity and adequacy that the student encounters the problems of construction of models, both physical and mathematical. Equally important is instruction in the deductive and predictive consequences of theories. From the detailed examination of both the comprehensive theory and its incorporated laws, the limitations upon the reliability of scientific explanation and prediction become apparent: (a) limitations in the statistical sense of probability statements; (b) inherent limitations from the application of exact mathematical relationships to physical data and models which can only approximate the real phenomenon; and (c) limitations on the range of phenomena susceptible to scientific methodology.[5]

(F) Teleology and values. Although the natural sciences tend to avoid postulates

$$s_2 = \begin{bmatrix} a_{22} \\ a_{32} \\ a_{42} \end{bmatrix} ; \qquad g = \begin{bmatrix} s_2 & s_3 & s_4 & s_5 \end{bmatrix}$$

$$g = \begin{bmatrix} a_{22} & 0 & 0 & 0 \\ a_{32} & a_{33} & a_{34} & a_{35} \\ a_{42} & a_{43} & a_{44} & a_{45} \end{bmatrix}$$

Figure 4-1. Generalization submatrix

$$A_1 = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & 0 & 0 & 0 & 0 \\ a_{61} & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 4-2. Total submatrix

of a goal-directive or purposive type, it is not uncommon to encounter teleological explanations in the sense that there are attempts to establish functional purposes of each structural and movable part in complex objects or processes.[6] An equally significant element visible throughout undergraduate science instruction is the presence of human value judgments in a variety of forms. The value system of the particular social order and the ethical reference frame of the scientist obviously influence the applications of the sciences; however, the role of value judgments in the very selection of trial hypotheses and the acceptability of explanations must be included as well.[7]

The structural elements summarized above can be used to construct the specialization column vector for a science discipline (S_1). It should be recognized that each a_{mn} entry is a composite vector ultimately resolvable into component segments.

a_{11} = values for functional and utilitarian science

a_{21} = theory development and analysis

a_{31} = hypothesis formulation and testing

a_{41} = observational techniques and skills

a_{51} = epistemology of science

a_{61} = verified and classified knowledge data base

The implied ordering of this set of elements is not the same as one of ranking in terms of importance, since each $a_i = b_i x_i$; and the total value of a_i will be determined by the scalar coefficient b_i whose assigned value will differ from one science field to another. For example, the coefficient b_6 will be larger in zoology than in physics, while the opposite will be true for b_2. The total matrix for the scientific disciplines is shown in Figure 4-2.

Within the matrix model it is the element a_{11} which is most responsive to the social change functions, while the time dependent elements a_{41} and a_{61} are also highly variable. By contrast epistemological facts (a_{51}) and the procedural aspects of hypothesis formulation (a_{31}) are nearly constant elements over prolonged time intervals.

It can be argued with considerable justification that a submatrix model is more suitable for the curricula of the fundamental sciences than for the applied sciences or engineering. For areas stressing applications of science to the requirements of social systems, the educational function must be much more responsive to the rate quantities for social change, technological change, and value changes. Thus, it might be more appropriate to extend the socio-economic model in Figure 1-7 to curricula serving the applied science areas.

Much effort has been directed toward the organization of the instructional content of the physical and biological sciences around the large overarching theories or concepts shaping those disciplines. For example, evolution and the mechanisms of heredity have been common themes for lower division sequences in the biological sciences; and the study of the multitude of forces and their relationships to derived parameters has provided the major underpinning for the first courses in physics. Thus, by giving the larger emphasis to the concept-

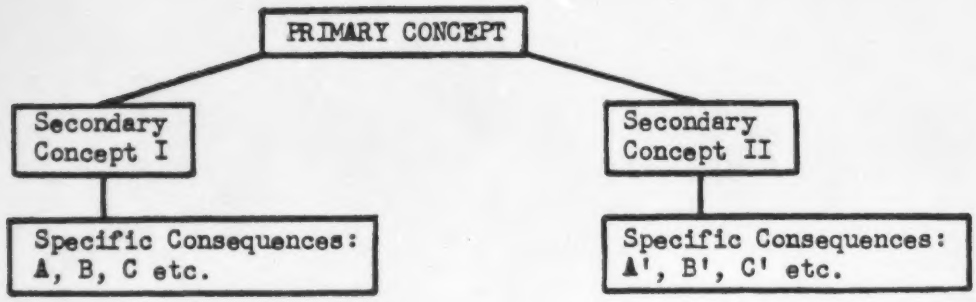

PRIMARY CONCEPT
Secondary Concept I
Secondary Concept II
Specific Consequences: A, B, C etc.
Specific Consequences: A', B', C' etc.

Figure 4-3A. Conceptual structure as a hierarchal system

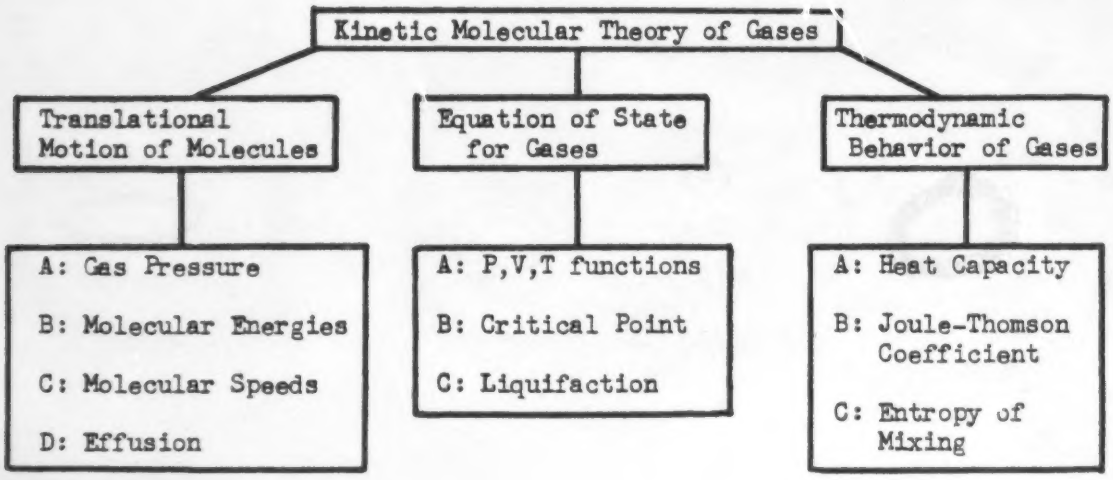


Figure 4-3B. An incomplete conceptual structure for physical properties of gaseous molecules

ual framework for the discipline rather than to the process elements in the field, the composite but elevated role of generalization becomes more confined in scope and simpler modelling procedures can then be used.

The diagram in Figure 4-3A is a general representation of the hierarchical relationships within any unified conceptual structure for organizing a disciplinary field. Here the most inclusive concept appears as the first entry (i.e. evolution or physical forces) and the subordinate, derived, or less inclusive concepts are given secondary ranks. Connective lines identify the essential relationships between the primary and secondary concepts and also schematically place the specific empirical data or observations which support and illustrate each secondary concept directly. Obviously, such concept diagrams give an overview of some aspects of the discipline and can be used both for curriculum organization and as models for integrating instruction within the field. For the latter purpose, the model would imply an essential role for differentiating and comparing various secondary concepts (horizontal relationships) as well as the formal deductive consequences of those concepts (vertical relationships).

Figure 4-3B illustrates a concept diagram for the physical properties of molecules in the gaseous state, using the kinetic theory as the primary concept. In this instance the theory is quite broad as a descriptive concept and includes a very definite quantitative foundational structure. Therefore, the secondary concepts assume mathematical functions can be derived from the primary theory; and many specific consequences follow which are testable both with experimental and simulated data. The primary concept can be extended as a supporting structure for the examination of the reactions of different chemical species in the gaseous state, as well.

Although a relatively simple device, the concept diagram can be very useful in designing nontraditional programs within the scientific disciplines. The many hierarchical relationships which exist in the major theoretical models employed in the sciences can be identified without difficulty and concept differentiation as well as derivative concepts can be traced clearly. If such nontraditional programs are intended to have a role in general education for a distribution requirement, then their central functions are less concerned with the structure of the particular disciplines than with viewing the scientific fields as sources for methods for learning about the interactive physical and biological dimensions of the earth. Such methods then show the primary and repetitive uses of measurement, logic, and the analysis of form as parts in common to all scientific modes of inquiry.

The Visual Arts

With respect to format and objectives the curricular patterns for the undergraduate education in the visual arts differ greatly from the major programs in the natural sciences. They do share the common property of a strong specialization which may be directed toward pre-professional training. However, beyond such superficial likeness, the visual arts stress the development of skilled performance on the part of the student through the dual emphasis upon both the creative process and the product. In the educational philosophy for the visual arts a high value is given to the historical dimension of the processes and the social-psychological contexts of the discipline.

For the highly structured and confined B. F. A. curricula with many

credits required in studio courses, a much greater weight (magnitude) is given to the vectorial contribution of the creative process itself. That process element in creative performance is intended to develop within the student the capacity to create or discover a problem requiring a visual solution in an appropriate medium as well as the capacity to explore and to ultimately produce an adequate visual solution to that specific problem. The latter involves the manipulation and re-ordering of both the artist's and the observer's visual perceptions of the created problem. Thus, the acts of problem-discovery and problem-formulation are operational commons in the pre-professional education of students majoring in both the visual arts and the natural sciences although the outcomes of such activities obviously differ in form and disciplinary objectives.

One approach to the review of visual arts curricula is to begin with the verbal symbolic analysis of Susanne Langer cited early in this monograph. Although centered on pre-college art instruction, the educational implications of Langer's views summarized by Shoemaker identify a number of points common to all levels of instruction in the visual arts.[8] The two-fold classification of knowledge symbols given by Langer has been applied to paired subject fields, and those listed below are relevant to the visual arts.

HUMAN EXPERIENCE	DISCURSIVE	NON-DISCURSIVE
Creative imagination	Psychology	Religious experience
Memory	History and Biography	Poetry and Novel
Time	Astronomy	Music
Space	Mathematics	Visual and Plastic Arts

The contrasting impression of space, time, and memory in areas relying upon discursive and non-discursive symbolism is clearly seen.[9] Consequences for curriculum elements within the visual arts are:

(A) Utilization of intuitive perception of pattern and motion.

(B) Creative organization of symbols and materials.

(C) Unified approach to design and form in a given medium.

(D) Self-discovery through perceptive symbols and forms.

(E) Present expressions of human experiences compared to those of the past.

In general the traditional specific courses used to construct curricula in the visual arts have tended to convey different emphases to the student than these. They have stressed fundamental skills in design, organization, and manipulation in relation to each particular medium, and have been largely product directed. Period and regional art or cultural history have often been student experiences which are mentally isolated from the "doing" of the arts. However, both contemporary and traditional curricula in the visual arts can be examined from the viewpoint of the forces of generalization and specialization interacting within the discipline itself.

The triangular model depicting vectorial relationships in Figure 2-4 can be easily adapted to a structural presentation of visual arts curricula.

Vectorial elements for both specialization and generalization can be identified; however, it must be recognized that each is a compound vector composed of several vectorial parts which are additive.

The total specialization vector, S_A, can be viewed as the sum of the following component elements contributing to the cumulative process-oriented discipline.

s_1 = concepts of design and form

s_2 = media for products; potential and limitations

s_3 = skills in manipulation of tools and materials

s_4 = the creative process and the self; product vs. the experience

s_5 = analysis and criticism of the product

s_6 = process and product in the history of discipline

The item vectors have their individual magnitudes, and in contemporary practice s_5 makes a relatively small contribution while the larger terms are s_2 and s_3. Algebraically, the vector sum is:

$$S_A = s_1 + s_2 + s_3 + s_4 + s_5 + s_6 ;$$

and all s_i vectors will be aligned vertically in a head-to-tail summation. Because of this, the vector sum conforms to the commutative law so that the arbitrary numbering and ordering of the s_i elements is unimportant with respect to the value of S_A.

In a somewhat similar manner the total generalization vector, G_A, can be resolved into a sum of vector components and the following are a representative set of elements drawn from outside the discipline.

g_1 = drama and dance

g_3 = science of forces and materials

g_4 = psychology and personality theory

g_5 = literature and myths

g_6 = cultural history

The subscript numbers are chosen to indicate the correspondence between a given s and g vector pair. Although the total vector G_A is an algebraic sum of the g_i elements, the uniqueness and lack of any required dependence of one g_i-value upon another in the set suggests that the vector sum will not be obtained from a simple unidirectional alignment of the segments. For such a case, the parallelogram law can be used to obtain a geometric solution. The only restriction imposed by the model is that the final generalization vector sum be directed normal to the specialization vector. Within the set of directed segments, g_5 and g_6 have been the larger elements in relation to the traditional art media;

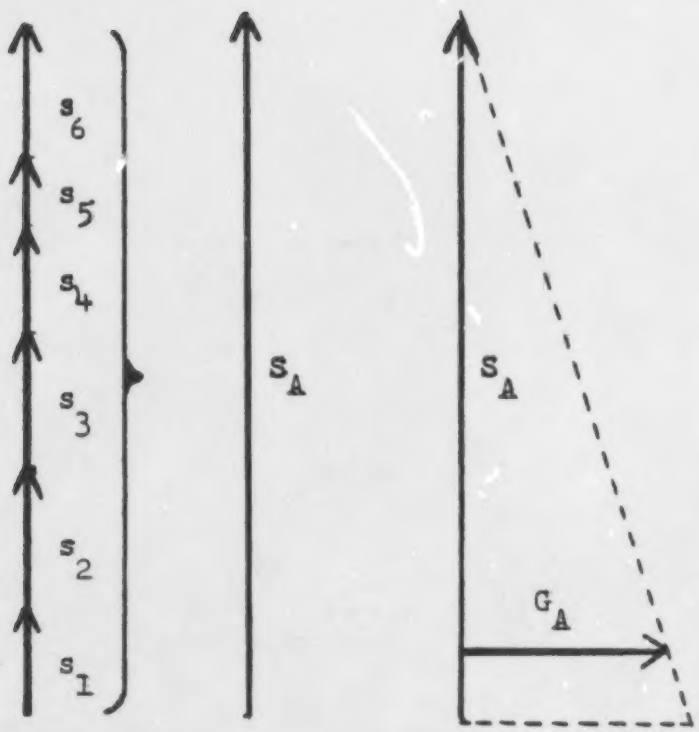


Figure 4-4. Visual arts curriculum

and g_1 and g_4 have assumed larger values in recent decades.

The completed triangular model for the visual arts curriculum is shown in Figure 4-4. This triangular orientation depicts the fact that the magnitude of the total generalization vector drawn from outside the subject field tends to show a systematic decrease as the degree (or length) of the specialization vector increases. In the extreme instance undergraduate specialization supersedes all but the minimal generalization in curricula leading to the B. F. A. degree. On the other hand, carefully planned generalization can strengthen the qualitative level of the creative process as well as the impact of s_1 and s_6 on the total vector sum.

There is no reason to conclude that the triangular vector model is the most appropriate representation for the visual arts curriculum. Like the matrix model for the natural sciences, the example is simply illustrative of an analytical interpretation of disciplinary structure.

Disciplinary Groups In The Curriculum

Within the liberal arts colleges it is not uncommon to find individual subject fields joined with related areas into cluster fields rather than assigning to each academic discipline the status of a department. Representative of this pattern are the paired fields: history and political science; physics and astronomy; mathematics and computing; and philosophy and religion. Of course, such a tendency arises in part from administrative necessity and staff size; however, one should not overlook the derivative educational import of the widespread practice in which an individual instructor has regular teaching responsibilities in two or more disciplines. With this arrangement the scope of a specific course in each area often becomes less restricted and the content can acquire a more cross-disciplinary emphasis. Such an outcome need not be an accidental occurrence, but it can be an intentional objective in constructing curricular models emphasizing structure within the disciplines themselves.

The broad area of the social sciences provides a number of examples adaptable to the development of models for cross-disciplinary groups. Michael Scriven has identified three approaches to the organization of the subject matter of the social sciences.[10]

(A) Interdisciplinary view - having a common subject matter but many specialties within that broad field.

(B) Multidisciplinary view - independent fields touching various aspects of human behavior.

(C) Reductionist view - a common mechanism and materialism that treats the social sciences as an extension of the natural sciences.

It is the conclusion of Scriven that the multidisciplinary view is the preferable stance for planning introductory curricula in the social sciences; and he argues for the three areas, history, psychology, and geography, as the central fields for all of the social sciences. Although one may not accept this particular set of fields as the essential or exclusive core, the multidisciplinary position can be extended through diagrammatic models.

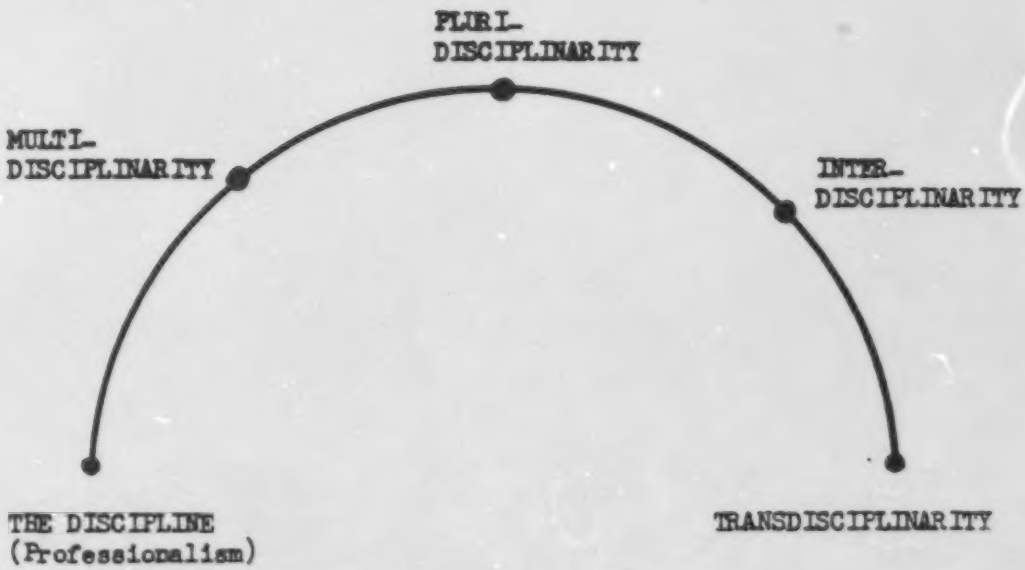


Figure 4-5. Continuum of disciplinary interactions

Another view of possible interactions among the disciplines has been proposed by Swora and Morrison[11] and this is represented by the continuum in Figure 4-5. The curve depicts the progression in terms of the degree of methodological cooperation and moves from a parochial position (the discipline) toward a wholistic interchange (transdisciplinarity) without disciplinary boundaries. In this context an interdisciplinary position retains the identity of the origins of the particular disciplines while stressing dialogue and the evolution of new concepts, languages, and methods. The term, pluri-disciplinarity, describes a tool or skills-type of dependence of one field upon another and is shown by the universal role of mathematics in the physical and social sciences.

One form of multidisciplinary convergence in the social sciences is illustrated by the problem-solution approach used in some general education sequences centering on contemporary human society. The directional approach to the given learning situtation is either from the discipline toward illumination of the problem or vice versa. In so doing it is recognized that the whole problem is being fractionated by the separate disciplines and each is contributing in a partial manner to the analysis and/or solution.

As a representative example, we may use the simple epistemological problem: "How does the individual know?"; and we may examine various viewpoints or positions contributing to knowing. One can immediately identify three disciplines which relate to the problem, namely psychology, philosophy, and religion; and in the extreme they represent the three unique origins for viewing the problem -- phenomenalism, rationalism, and revelation (or institutionism), respectively. In order to show trends in the real process of knowing the interaction of these three determinant fields would require a three-dimensional coordinate system. However, this representational problem can be simplified by using the observation that any position point is the result of the fractional contributions of each of the three parts. (Or, in terms of the idea of percent each disciplinary coordinate contributes to the whole such that the sum of all is always 100%.) The Roozeboom triangular diagram is particularly suited to graphical problems in this form and has been widely used as a planar method for depicting phase relationships in ternary mixtures of materials.[12] Figure 4-6 is an application of such a triangular coordinate system to the interaction of the three-fold variables in the question above.

It is only at each vertex of the equilateral triangle that the "purist" view of knowing is shown (i.e. the rationalism of philosophy to the total exclusion and rejection of phenomenalism and intuitionism, etc.). Along any edge of the triangle, two-fold connections could be developed. For example, various traditional theological positions determined by weighting factors w_i (as percentages) can be placed as points between A and C without including the effect of B.

None of the following classical positions on the questions of knowing will exactly coincide with the purist views (A, B, C); and as geometric points in Figure 4-6 the essential restriction is that

$$w_1A + w_2B + w_3C = 100 .$$

The sequence is one showing a decreasing influence of the rational in determining that position.

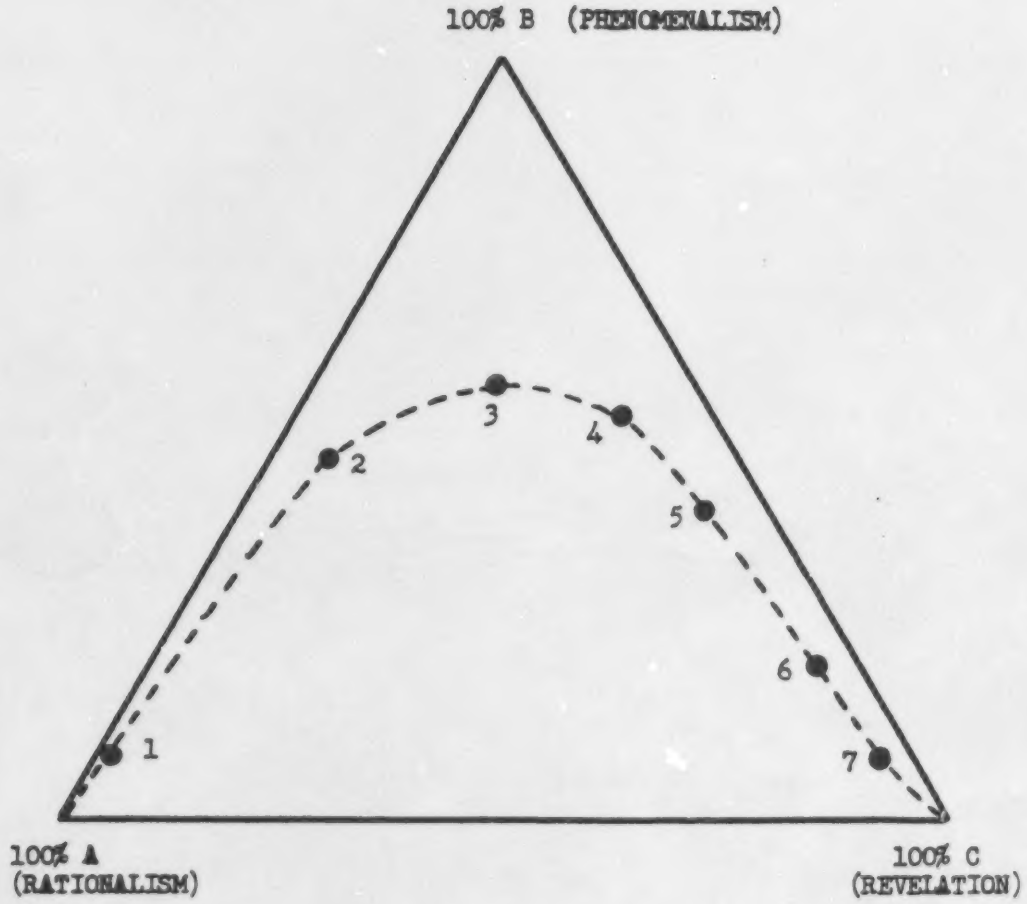


Figure 4-6. Triangular coordinates for the problem of knowing

Point No.	Position	Relative Importance of W_1
1	Linguistic Analysis	$(w_1 > w_2) >> w_3$
2	Scientific Empiricism	$(w_1 \sim w_2) >> w_3$
3	Majority Opinion	$(w_2 > w_1) > w_3$
4	Cultural Tradition	$(w_2 > w_1) > w_3$
5	Expert Opinion	$(w_2 \sim w_3) >> w_1$
6	Charismatic Authority	$(w_3 > w_2) >> w_1$
7	Existentialism	$w_3 >> (w_2 > w_1)$

Since the weighting factors are only in semiquantitative terms, the locus of the points is more of a band than a precisely determined curve. Nevertheless, it is along the curve that interfacing of the three disciplines gives rise to a series of definable positions as particular solutions to the question of knowing.

Other multidisciplinary examples susceptible to treatment by the triangular coordinate system come to mind. Problems of visual perception in the arts as approached from psychology, physiology, and the visual arts might be used. Or, energy flow in a contemporary industrial society can be resolved into factors from economics, political science, and physical science. Of course, quite differently shaped interfacing curves are possible besides the simple one shown in Figure 4-6; and these would be expected to be more precisely defined in systems delineated by quantitative parameters.

The association of departments into larger administrative units within the university setting has been investigated by Faricy,[13] and some of his findings are relevant to the corresponding problem within the liberal arts college. In seeking to identify clusters of departmental traits Faricy assigned six primary elements to a department; and three of these must be supportive in any cross-disciplinary efforts, namely objectives, functions, and subject matter. However, it seems necessary to add one more element to this list, the instructional mode, since particular techniques and learning methods receive different emphasis in one department as compared to others. For example, independent study is often used in the humanities, laboratory studies are important in the natural sciences, and the apprentice relationship is applied at several levels in the fields of education and business.

If empirical clusters of departmental traits can provide a more rational basis for organization of instructional units within a college, then an anticipated dividend would be increased opportunity for multidisciplinary learning outside of the traditional departmental boundaries. Such disciplinary clusters would have a greater potential for teaching problem-solving than the more fragmented departmental entities having a confined cognitive base. Specialized studies in the major area are then placed within a broadened context and are extended beyond the acquisition of skills and knowledge expertise through disciplinary interactions.

Fraley and Vargas maintain that the traditional departmental and disciplin-

ary organization, having focused upon content, is incapable of serving an effective instructional role and of utilizing the newer educational technology.[14] If the major objective of teaching is training at high levels of skills and modification of cognitive behavior, then a different organizational arrangement centered on the modes of instruction and evaluation of performance is needed. Fraley and Vargas have developed a comprehensive industrial processing model which is intended to solve this technological problem of instruction in a university setting. Beyond an administrative division, the main organizational units of the system are:

A. Curriculum and Design Division - including the functions of need, materials, and content analysis and selection.

B. Production Division - preparation and distribution of instructional technology.

C. Operations Division - instructional spaces management.

D. Quality Control Division - evaluation, analysis, and feedback (to A,B,C).

Whether or not the individuals serving in the Design Division and the Instructional Operations Division can become the "new generalists" needed for directing liberal learning is clearly an unknown. The technology of instruction is but one of several variables structuring the totality of a learning environment.

Although a greater variety of instructional strategies have been utilized in recent years, the disciplines themselves are largely circumscribed by a commitment to rationalistic and empirical structures in both the liberal arts colleges and the universities. Modes of instruction as well as the organization of introductory college level textbooks have shifted somewhat toward formats in which cognitive and conceptual structures are stressed within disciplinary learning. However, beyond the introductory courses each of the disciplines remains centered on its unique store of basic factual knowledge, methodology, hypotheses, and skills which its students must master. Revisions of disciplinary programs usually focus initially upon content issues: the fundamental boundaries of the field, the selection of topics, and the order of subject matter in relation to pre-requisites from within the discipline and from the cognate areas.

Regardless of the complexities and intricacies inherent in the subject matter of the discipline, an organizational and indeed a conceptual scheme becomes essential if the massive content of each discipline is to be manageable for the student. Although humanistic areas may appear to lack an obvious structure or their domains may be formally ill-defined, it is nevertheless possible to build a skeletal framework forming a coherent field of study from the subject matter of each field of learning.

If a college wishes to move away from the traditional departmental organization and its close association with curricular forms using logical and conceptual structures, it is possible to re-group the subject matter fields into more multidisciplinary categories to permit broader major programs. Three such groups are identified in the following table in which each is characterized by recurrent themes and comparative perspectives on values and meaning in the related fields of study.

Artistic Group	Literary Group	Human Behavior Group
Music	Prose and Poetry	Psychology
Dance	Linguistics	Sociology & Anthropology
Visual Arts	Foreign Language	Human Philosophy
Creative Writing	Drama	Political Science

By contrast to the major programs in the natural sciences, each of these groups confronts contemporary problems centering on attitudes of individuals and groups as well as information; and each lends itself to either cognitive or existential structures for program organization while assuming its students possess basic communicative and learning skills. Each should call for a variety of outcomes of learning beyond simple verbal information, moving at least toward a meaningful transformation of the known into an enlarged context. Since attitudes are learned and determine both the personal preferences and likely choices for action or inaction, the influences of attitudes on the learning outcomes must be a major consideration in each group of fields above. The goals for thoughtful analysis and the resolution of problems in each field should lead to a new perspective on differing points of view and a sensitivity to not only differing beliefs and feelings but also differing modes of expression and social action. An understanding of interpersonal and group behavior is as much a given within each study area above as the acquisition of broadened cognitive-interpretative skills when seeking solutions to particular problems originating with interacting persons, cultures, and ideas. Unfortunately, the dominant pressures from the graduate and professional schools and prospective employers of our students discourage any drastic re-alignment of the subject areas into non-traditional groups.

Organization of a given discipline for undergraduate instruction, whether its content is new or traditional, requires value-based decisions about significance and authenticity of its subject matter. Similarly, the process of selection of content elements for a disciplinary program of study is synonomous with a reduction to seminal ideas and a simplification of the learner's task. The specialists in the field know that the information products of disciplinary inquiry may be more transient than the methods leading to common conclusions. Hopefully, the selection process will assemble a content having the potential for arousing the curiosity and the imagination of the learner. Like the curriculum as a whole, our efforts toward the development of such unitary structures for the discipline can benefit from the auxiliary use of visual models which demonstrate the fundamental interdependencies among the component parts of the given field.

As we search for alternative intellectual structures for organizing disciplinary segments in the curriculum, the iconic model seems to be superior to a sentential representation for elevating the key processes and contents receiving special emphasis. In developing the iconic model one must return to the complex domain of the discipline itself as the source of contents and concepts to be used. The structure to be incorporated into the model must be real, not merely fabricated from our idealized philosophical goals. Likewise, it should mirror essential processes or behavior as it organizes the real intellectual activity unique to an area of study. In one sense the causal and plausible connections so established between the model and the reality of the disciplinary sources serve to restrain the imagination of the model builder, but only to the extent that pictorial symbols for the structure or processes are bounded by our rational understanding of real disciplinary learning.

Chapter V

PATTERN RECOGNITION AND THE METAPROBLEM

In each of the preceding models the initial step in their formulation is selection of a minimal set of primary variables which are seemingly interrelated in some way. Just as each model is based upon definite axiomatic assumptions, so also is each such systematization grounded in certain empirical information entries measuring knowledge structure, learning processes, social environmental factors, etc., which have been isolated from the total array of educational data items. Up to this point, the choice of empirical factors and the assignment of functional roles to them which contribute to either generalization and/or specialization was derived from the rational arguments found in educational research of others. Thus, the very basis for the decision-making process itself as a preliminary step in formation of the curriculum model has not been examined; and, yet the metaproblem of seeking to improve the methodology of model construction must include such a fundamental element in the total procedure.

An excellent overview of the place of systematizing of human experiences in education as process has been given by Louise Berman.[1] She has observed that the beginnings of all attempts at patterning or modeling require the development of criteria for selecting and deleting categories. Such categories are simply special groups of phenomena, items, facts, or data in classes sharing common identifying properties. However, any further organization of these categories implies decisions on a larger scale for both a selective ranking scheme and a workable method of correlative ordering.

The area of mathematical analysis called pattern recognition suggests some helpful techniques for identifying the rules of correspondence within complex sets of variables.[2] For properties as difficult to quantify as a list of learning factors, these techniques give clues to the description of functional connections between categories which may not be visible to a more superficial examination. As was the case in the earlier section treating the vector and matrix models, the approach here will be to sketch a few potential applications for pattern recognition techniques in curriculum modeling without either mathematical rigor or comprehensive generalities being imposed. However, even a brief introduction to the methodology of pattern recognition provides some insights into the fundamental and necessary process of sorting and relating the categories used in the various diagrammatic models.

The processing of the fact-data obtained from a given measurement system can proceed separately along either of two lines of inquiry or in combination: (a) a theoretical interpretation in which a specific causal relationship derived from earlier data or from a logically formulated model is tested; and (b) an empirical interpretation in which it is assumed that some defined categories exist independently of established theories although the connection between the categories is unknown. The simple vector models for liberal arts curricula illustrate the former approach; however, the empirical method is capable of evolving other working models through decision-making and generalization of deductions. The information items (data units) are considered to be vectors in the sense that their graphical representations are geometric points in coordinate space, and the empirical methods of pattern recognitiion are applied to their analyis.

Terminology

A diagrammatic outline of the pattern recognition approach is shown in Figure 5-1a, and, because of the somewhat specialized use implied for the terms given there, it is necessary to define some of them operationally.

1. Parametric Methods. Procedures for recognition assume that the underlying statistical distribution of the quantities or classes of information are known or that probability functions can be estimated.

2. Nonparametric Methods. No assumptions about the statistical distribution of the measured items are made. Since statistical inferences about the many categories of learning factors involved in education as process are unknown, curriculum model construction is placed in the nonparametric branch.

3. Pre-processing. (Note that the pre-processing step can be by-passed.) This involves numerical operations on the individual measurements or information items in some manner to change the way in which the information is represented. Pre-processing can include such simple algebraic transformations as taking logarithms, raising to powers, or extraction of roots, and more complex operations like the Fourier transform. One value of initial transformations on the measured items is that the categories may be more spread out in geometric space, thereby making correlations between categories easier to determine. A second value of pre-processing is that it may be possible to reduce the number of dimensions required to represent the categories in a graphic coordinate system. However, since decisions are necessary in this pre-processing stage, a biasing influence enters the empirical method from this source.

4. Classification and Learning Methods. At this point computerized techniques are applied to the pre-processed information with the objective of solving the problem of finding clusters of data items, artificially generating an approximation of the grouped information, or classifying unknown items in terms of their proximity to known categories.

5. Supervised Learning. As a learning method, the supervised type refers to the comparison of specific items or data to a known classification scheme in order to develop a rule of correspondence which applies to both known and unknown information. The group of known items and their categories comprises what is called the training set.

6. Unsupervised Learning. Here, the purpose is to search for clustering of categories as evidence for some rule of correspondence in the absence of any known classification system. In this instance no training set is available, and it represents the condition found in most factor comparisons in curriculum analysis.

If we now restrict our attention to the basic operations used in pattern recognition techniques, the simplified diagram in Figure 5-1b is a suitable representation of the usual sequences for the essential steps. However, an optional and more complete view of these sequential steps is shown in Figure 5-1c as a specific example of the general modelling cycle discussed in Chapter I.

Of course, the starting point for the cycle is the raw data or set of

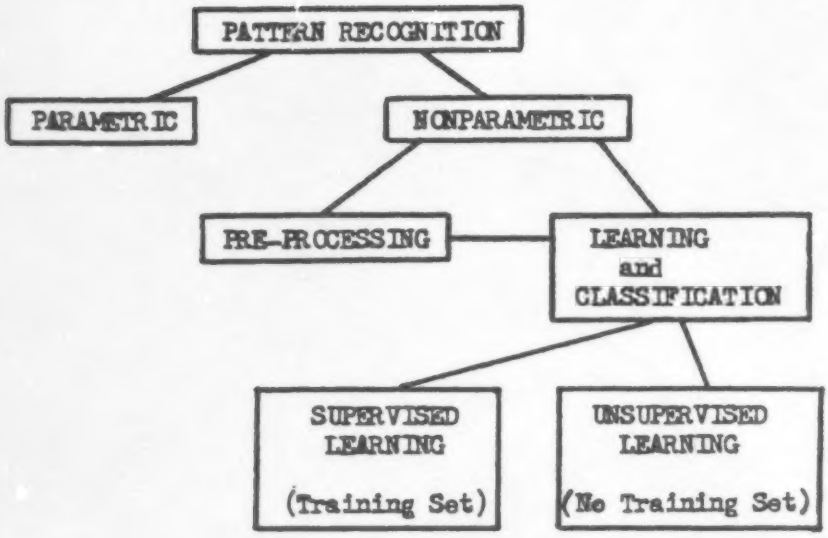


Figure 5-1a. Brief schematic for pattern recognition.

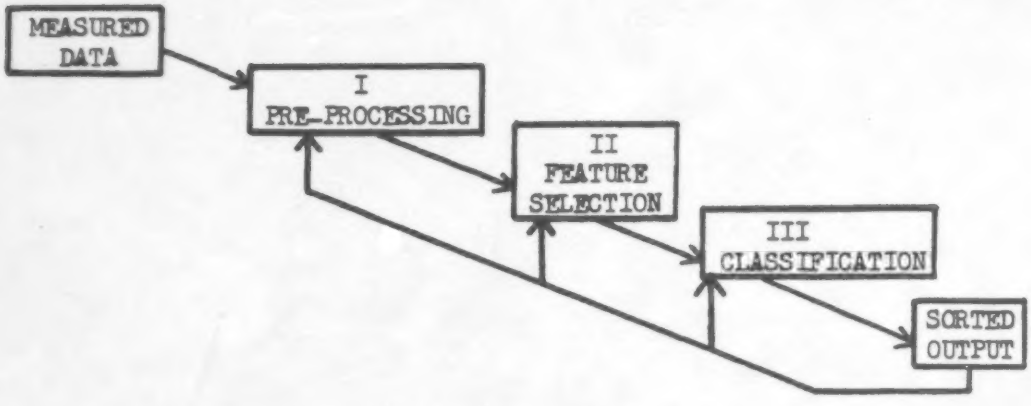


Figure 5-1b. Operational steps in pattern recognition.

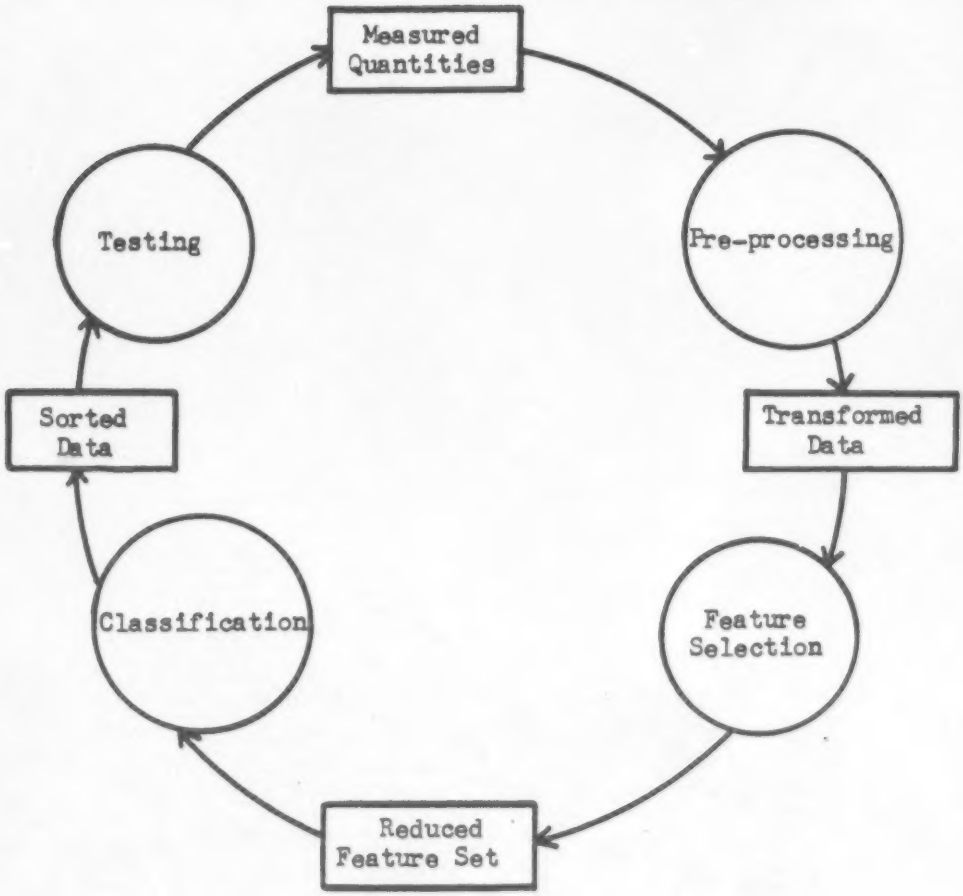


Figure 5-1c. Pattern recognition as a modelling cycle

measured quantities; and in the broadest sense the internal make-up of that set may include data of widely varying magnitudes as well as even different units. Thus, the initial operations in the preprocessing step may be designed to simply adjust or reduce the variations in magnitudes of numbers within the data by applying scale factors, or to normalize the data with respect to certain reference values having special importance. On the other hand, for an undifferentiated set of data, the scale factors may be needed to produce more useful descriptors for later manipulations.

In the second step the objective of the operation is to eliminate extraneous features from the data set and yet retain the minimum number for the subset without distorting or invalidating the final resolution of the data into categories. One consequence of feature selection is the simplification of later computational procedures used for classification by reducing the number of variables required to characterize the measured quantities.

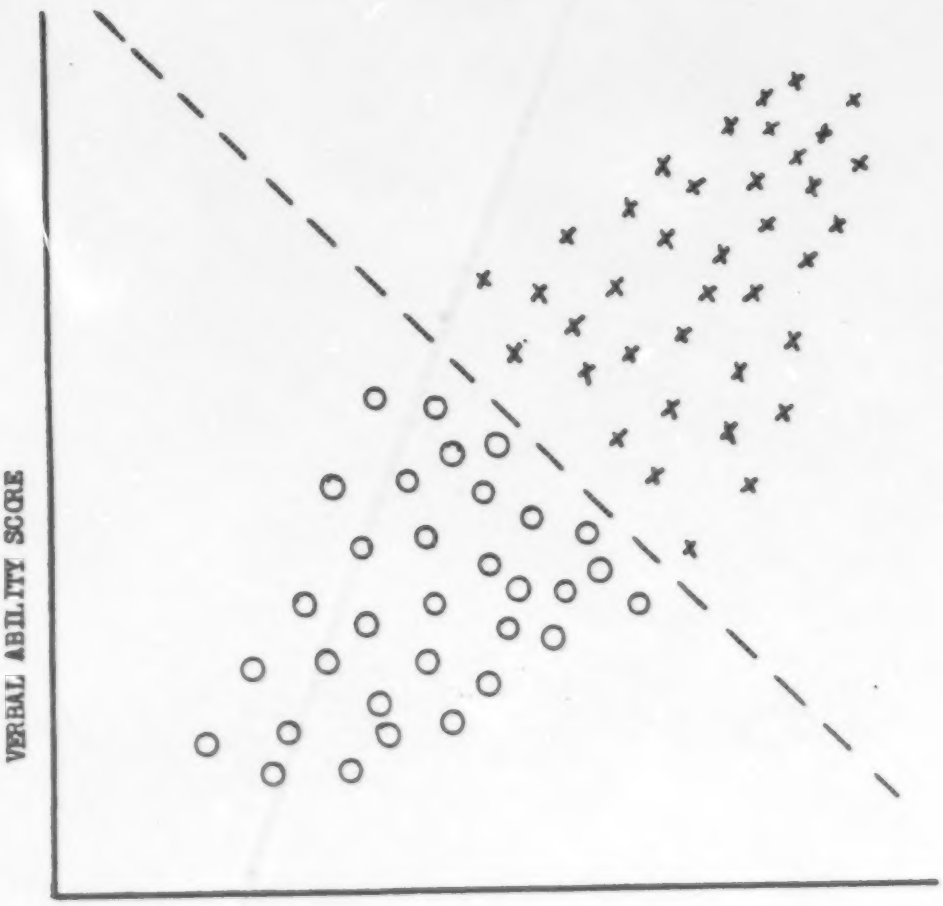
The final operational step is to adequately identify each item in the data set by placing it within some pre-defined category. In its simplest form this can be demonstrated graphically by observing the locations of each of the measured data points in relation to its neighbors in two or three dimensions in which selected features (parameters) are used as the axes. Then, a line or a plane can be drawn in the coordinate space in such a manner that a boundary of separation is formed between the categories of data points. However, mathematical functions more complex than linear equations may be necessary in order to establish the real surface dividing the data into separable classes. Normally, the training sets will be needed to identify trial patterns to be used for the classification step.

The cyclic process depicted in Figure 5-1c emphasize one of the essential requirements for all pattern recognition procedures,namely that comparisons between the outcomes of the real classification and that with the training set are subjected to error analysis and correction. Such operations dictate feedback mechanisms at various steps as well as the repetition of the total cycle starting with changes incorporated from the preprocessing step onward. As shown in Figure 5-1b, the feedback cycles can be applied at any operation-outcome segment in the total sequence: i.e. preprocessing, feature selection, and classification. Obviously, the intent of such feedback loops is to reduce the errors contributed by each of the operations in order to improve the reliability of the final results of the classification scheme.

Applications

Pattern recognition methods have as a major objective the identification of an obscure relationship or property from a collection of information items through the use of indirect measurements made on those items. The significance of this goal will be illustrated first by using information from standardized testing of entering college students.

In Figure 5-2 the verbal ability scores of first year students are plotted against the social science achievement score obtained on the same battery of tests without any preprocessing of the data. Although the two variables correlate positively, the additional function of cultural biasing becomes apparent when the first spoken language of the student is indicated as well. Thus, there is a clustering of the data into two categories even though each point in the two-dimensional space defines a pair of measured items (verbal



x - First language English

o - First language Spanish

Figure 5-2. Two-dimensional pattern recognition including a linear decision surface.

score and social science score). The points can be thought of as representing vectors in two-dimensional space, and the graph clearly suggests that different cultural origins place the test scores into two separate groups. Since the pattern points of these two classes can be divided by the dashed line, they are said to be linearly separable in two-dimensional space and have a linear decision surface.

In comparisons between the two classes in Figure 5-2 the similarity of any two data points can be expressed by their nearness in space. Let S be the measure of similarity of the two vectors x_1 and x_2 separated by a distance d_{12}; and the interpoint distance can be expressed as a value relative to the maximum separation (d_{max}) of any pairs within the same category. Then, the similarity function has the form:

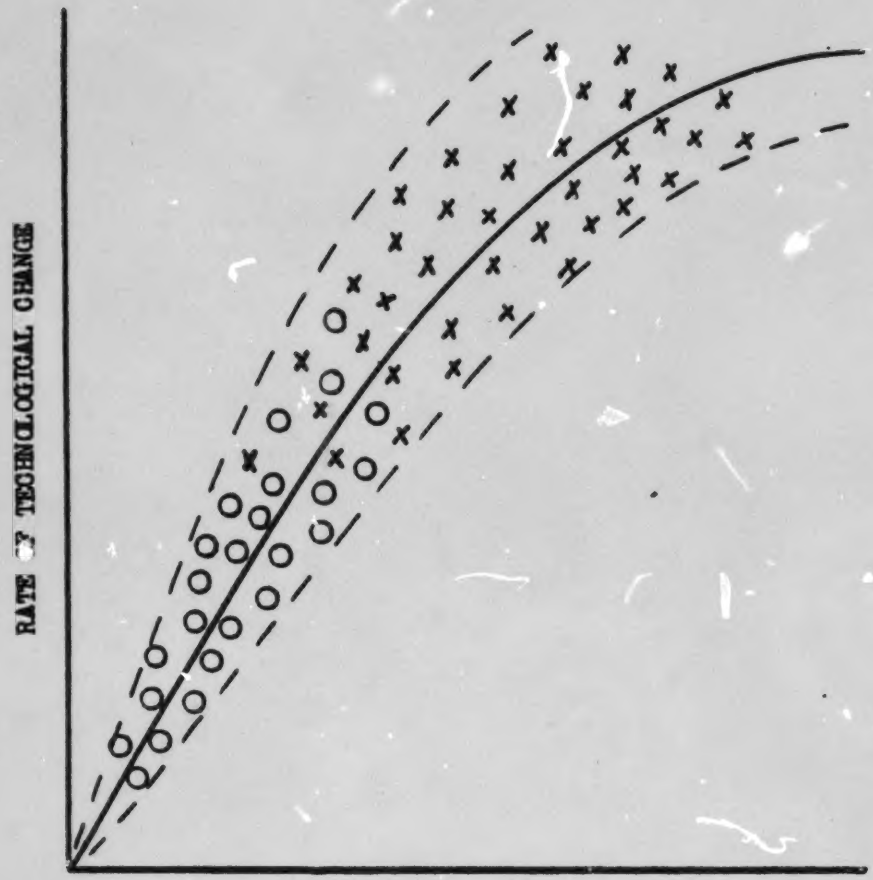
$$S_{12} = 1 - \frac{d_{12}}{d_{max}} ;$$

and, as a criterion for similarity measurement in the pattern, S_{12} is unity for identical points and is zero for points widely separated from each other. Thus, the similarity function gives a quantitative basis for classifying the item data.

One obvious consequence of the resolution of the trend in test results shown in Figure 5-2 is that the designer of the curriculum as well as the classroom teacher must not assume the student group is homogeneous in either its input learning skills and attitudes or in its cultural experiences and educational goals. The common dependence of both communicative skills and progressive learning in the social sciences upon the early cultural or ethnic experiences of the students necessitates a modification of learning strategies selected at the college level, particularly in those dimensions falling in the general education core. Geneva Gay[3] has proposed that the general studies portion of the curriculum be designed to reflect the realities of the culturally pluralistic student population by using any one of several focal points:

(a) comparative ethnic differences and cultural traditions in American society;
(b) recurrent themes in common to all human cultural groups examined within the context of ethnic experiences (justice, freedom, the family, etc.); and
(c) multiethnic concepts of identity, symbolism, acculturation, change, and communication. Thus, the curricular components in the social sciences serving the "general student" will be interdisciplinary in content while ultimately modifying attitudes, behavior and basic communicative skills for such students if appropriate instructional methods and materials are employed.

A second application of pattern recognition methods in educational problems will be drawn from the economic model for the curriculum as proposed by Goldman, Weber, and Noah.[4] In the earlier discussion of this model in Chapter I the relationship of the two rate quantities, social change and technological change, was given in Figure 1-7 as an empirical function where social change shows an almost linear increase with technological change over a long interval. However, the curve is by no means precisely defined and, as the two coordinates increase, so also does the scattering of the points (uncertainty) from which the smoothed curve is derived. This characteristic of increasing uncertainty is shared by all technological indicator functions.[5] Therefore, a more accurate



o - General studies function

x - Specialized studies function

Figure 5-3. Patterning in the economic model for curriculum planning.

representation of that rate-rate plot can new be re-drawn as Figure 5-3. Although it is likely that the upper portion of the curve levels off toward some limiting rate for technological change, the supporting data are not capable of defining where this will occur.

Empirical evidence suggests that the rate of technological change is proportional to the societal investment in resources and expectations, and it is some force or constraint which ultimately establishes the asymptotic limit for the rising rate of technological change.[5] With respect to the curriculum Goldman, Weber and Noah conclude that the effect of specialization upon the rate of technological change is greatest in the upper half of the rate-rate graph. Such a conclusion seems justified since the technological function alone tends toward an exponential increase in long term projections.[5] On the other hand, because of the sigmoidal growth curve for particular technological developments, the general studies function will be the more important curricular parameter in the lower portion of Figure 5-3.

If the total curriculum is divided into only the two parts, generalized studies (A) and specialized studies (B), then the fraction of the total curriculum assigned to each will be F_A and F_B. Obviously,

$$F_A + F_B = 1$$

and the total rate-rate function can be obtained from data items related to the specialization function alone. On the other hand, if the conclusion of Goldman, Weber, and Noah noted above is used, then the locus of the lower points in Figure 5-3 will be largely determined by the general studies fraction and the upper curve by F_B. The central region of the curve will contain a strong intermingling of points originating from both A and B. Although not as distinctly separated into categories as in Figure 5-2, the rate-rate graph exhibits a clustering of points having a poorly defined linear decision surface. More than simple visual inspection is necessary in order to locate that surface, and the outline in Figure 5-4 describes a solution to the problem. For simplicity, it is assumed that a linear decision function can be found which will separate the data-points into two classes. However, it must be noted that not all of the intermingled points can be placed correctly into two fully distinct clusters by using a linear discriminant function alone. (For other techniques, see Appendix 2.)

Any training routine which might be devised will attempt to define a planar decision surface such that all data points belonging to class A are on one side of the surface and all not belonging to A are on the other side. From a geometric point of view, the decision surface can be represented unambiguously by a vector W perpendicular (normal) to the plane and a point lying in the plane. The mathematical equation relating the quantities includes the angle θ between W and X;

$$W \cdot X = (W)\ (X) \cos \theta$$

and it is ultimately the algebraic sign of the quantity ($\cos \theta$) which determines on which side of the decision surface a given point x lies.

A series of information items $x_1, x_2, x_3, \ldots x_n$ can be considered to be parts of an original pattern vector X; and a decision surface for the pattern

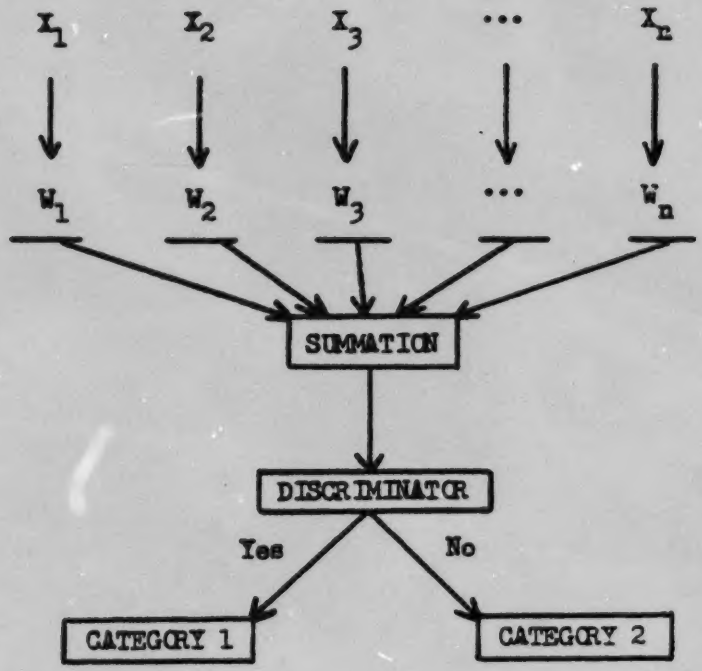


Figure 5-4. Schematic for a binary classifier.

can be defined by a function of X which is single-valued and scalar. However, if the original pattern is to be subdivided into two new categories, the new pattern vector Y is introduced and a weight factor W determines whether or not a given point lies on one side or the other of the linear decision surface. Stated mathematically, the original function f(X) involves weight factors (w) just as the final pattern vector Y.

$$f(X) = w_1x_1 + w_2x_2 + w_3x_3 + \ldots + w_nx_n$$

This is shown in the first step (summation) in Figure 5-4.

The discriminator (or pattern classifier) uses Y and W to produce a scalar output (s) such that $s = W \cdot Y$; and s has values +, 0, or -, depending upon which side of the linear decision surface the product is. (The dot product means: $W \cdot Y = w_1y_1 + w_2y_2 + w_3y_3 + \ldots + w_ny_n$.) Therefore, the decision of the discriminator for classifying the x_n-points is as follows.

$W \cdot Y > 0$, place in category 1

$W \cdot Y < 0$, place in category 2

With reference to the economic model for the curriculum, the points for the specialized studies function would be placed in category 1 and general studies data fall into category 2.

In real applications of the binary classifier the actual weight factor (W) is unknown and it becomes necessary to use a training set to calculate corrected weight parameters which will represent the anticipated pattern as reliably as possible. Repeated cycles through the training set and repeated corrections of weight factors are achieved by computerized training and testing programs. The special requirements for learning machine methods when used with similar scientific problems have been reviewed by Isenhour and Jurs.[6]

Many attempts have been made to develop plans for curriculum organization through empirical correlations of educational factors which cannot be measured numerically. In some instances the importance of a factor may be given an ordinal rank in comparison to others and this manipulation has the same effect as multiplying a data point x by a weight parameter w. Thus, if a suitable coordinate space can be designed to represent the trial correlation, some aspects of pattern recognition should be applicable to the system. If nothing else can be done, the similarity function can be evaluated for information items within tentative categories. For more quantitative data points, a variety of empirical pre-processing steps may lead to separation of items into visible patterns.

Two dimensional variable-by-variable plots are useful forms for the display of data items because they greatly reduce the quantity of verbiage needed to convey the essential information. Such display forms are valuable only if the data are not so complex as to become totally non-representable in two or three coordinated space. When the likely number of variables is limited to three or less, the human mind is the best device for pattern recognition. However, if the structure of the data is much more complex, then mechanical operations on that data will be necessary in order to reduce the number of dimensions required for display. To accomplish this, preprocessing, cluster analysis, and classification techniques can be used in combination as a systems ap-

proach to the processing of multivariable information sets.

The plotting of educational mission vs. means can be represented on a two-dimensional grid similar to Figure 1-6, and this has been used by Bruce Joyce as one procedure for correlating elements of the curriculum.[7] If enough unit factors can be identified, various re-orderings of the empirical elements along the coordinates would be expected to produce some initial patterning. This re-ordering stage is a form of preprocessing and Figure 5-5 illustrates the results of this step in dealing with several mission-mode variables in a sociology program. The ordinal ranking code that follows is one of increasing degree of other-directed learning in the mission and one of decreasing restriction on the learning process within the mode element. Although no single curve describes the mission-mode relationship in Figure 5-5, the initial preprocessing step begins to suggest a trend for correspondence between the contributing factors.

Educational Mission	Learning Mode
1 Research system	1 Programmed learning
2 Information processing	2 Logical reasoning (deduction and induction)
3 Emotional development	3 Intuitive-creative
4 Behavior modification	4 Directed group inquiry
5 Social interaction	5 Awareness (social consciousness)
6 Social problem-solving	6 Non-directive social inquiry

For a larger grid having many entries, the re-ordered pattern might give evidence of further groupings into two or more distinct categories related to educational modes.[7] However, in the absence of large amounts of numerical data measuring the variables shaping the curriculum, the great potential of pattern recognition methods cannot be fully utilized in the area of educational model formulation.

As processes for reducing empirical and related information into an understandable form, pattern recognition techniques serve more than one purpose for the user, and according to Uhr, the two most basic roles are characterization and classification.[8] In characterization the data items are designated in coordinate space of n-dimensions to the extent that enough features of the items are specified to adequately describe each item with variables in common to the whole set of items. Preprocessing may give rise to some sub-pattern units further characterizing the set of data items. By contrast, the classification role requires the selection of a discriminant function of the type that will divide the n-dimensional space into two regions by using a pre-selected pattern which will "recognize" or sort the total item set into groups of data belonging or not belonging to that pattern. To achieve this, some error correction feedback method is used to move the decision line or surface in space until the classifier sorts the items correctly.

Of course, the accuracy with which the classifier performs its role depends not only upon the reliability of the pre-selected pattern and its discriminant function but also upon the inherent difficulties within the data item set itself, i.e. non-representative sampling, too small a data set, or multicategory distributions among the data items making up the set. Although such data problems are common in education, the existence of both effects on

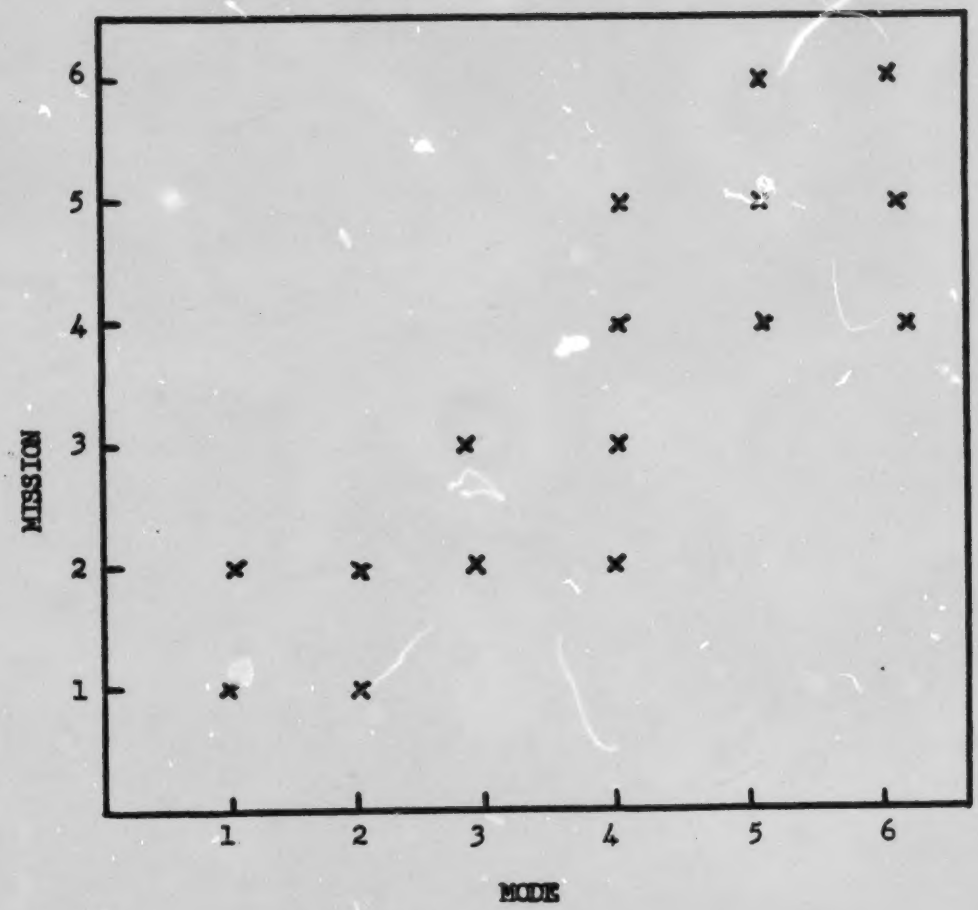


Figure 5-5. Learning in a sociology segment

classifier accuracy forces the user to apply some mode of evaluation of the classifier performance; and the most suitable measures of that performance are usually stated in terms of probability functions. For example, in a simple binary classification problem in which the two classes are designated by (1) and (2) and their probabilities of being present in the test set of items symbolized by p, the interdependence of the two probabilities must be

$$p(1) + p(2) = 1 \ ;$$

and, if N_T is the total pattern set and N(1) the number of patterns actually belonging to class (1), then

$$p(1) = \frac{N(1)}{N_T} \ ; \quad p(2) = 1 - p(1) = \frac{N_T - N(1)}{N_T}$$

After the classifier has operated on the data set, the outcome or real placement by the classifier can be stated as correct (c) or incorrect (i) for each class. Then, $p(1)(c) = \frac{N(c)}{N(1)}$; and

$$p(1)(i) = p(1) - p(1)(c) = \frac{N - N(c)}{N_T}$$

Similar statements can be obtained for class (2); however, if the binary classification problem is viewed as requiring only a "belong" or "not belong" decision, the interpretation of the performance of the classifier can be made in terms of class (1) alone. Performance measurements derived from such distributions between class members and nonmembers must be used with some reservations, since they are dependent upon the make-up of the total data set and are distorted by unequal class populations as well as by small and seemingly less representative data sets.

Several analogies can be drawn between the formal structures used in machine-assisted pattern recognition methods and the processes by which the human mind analyzes information received from the senses of sight and sound. Sensory stimuli may be instantaneous perceptions or extended over a considerable time interval as well as having enlarged spacial dimensions, and the mind must respond to these stimuli by recognizing them as familiar or unfamiliar through some comparative mechanism. The experimental work of cognitive psychologists has demonstrated ways in which the movements of information in the brain occur, with definite implications about human learning. For example, Reynolds and Flagg have suggested that the operation of mental recognition be divided into two steps: first, pattern detection in which the sensory stimulus is isolated from other impinging stimuli and encoded for neural transmission; and second, pattern interpretation in which the encoded stimulus is classified and given meaning.[9] One view of the second stage assumes that the mind stores a very large number of images or templates, particularly for visual and auditory information, and there is a mechanism for searching for a matching of the external stimulus with the exact or very similar internal mental template. Thus, the emphasis here is upon the uniqueness of the internal representation of stored patterns and, although it is a highly restricted interpretation of pattern recognition, a number of aspects of language instruction conform to this viewpoint. The rudimentary steps in reading printed words obviously involves direct association of nouns with specific visual images and letter sounds with encoded stored words or phrases. For reading to be

factually actually correct, the template matching must be exact both as a one-to one correspondence and contextually.

A second view of mental pattern recognition emphasizes the sorting and identification stage carried out on the encoded stimuli as a process in which several subunits of the incoming stimuli are identified as being in common to known features of stored information.[9] A given incoming stimulus, particularly from the sense of hearing, shows considerable variation from differing sources of the stimulus, and within these variations the pattern of word sounds must be sorted out by a process of feature selection which is then followed by feature interpretation. However, the latter aspect (interpretation) implies deliberate acts seeking relationships between simple features followed by a synthesis of a final completed pattern which then can be compared to previously stored patterns from long term memory.

Methods for teaching of communication skills and for factual instruction have been devised which draw upon these models for pattern recognition in mental processes. A brief discussion of an application to the information processing model for teaching will be given in a later section (Chapter VI).

Pattern Recognition and General Systems Theory

The field of pattern recognition with its underlying philosophical empiricism can be placed within the epistemological domain of general systems theory, though clearly in a subordinate role.[10] Because of this common ground, certain connections between the two areas which touch upon the construction of educational models should be noted.

A systems approach to problem-solving is wholistic and teleological with its primary emphasis being upon interrelationships between objects, items and data as the component elements in the total system.[11] The objective is the development of a structured and comprehensive analogy stated in a verbal, symbolic or mathematical form. However, the size of a defined system may range from the microscale of an individual molecule to the macroscale corporation, business or national organization. Variations and contrasts in structure, changes which the system may undergo, and probable outcomes from modes of behavior all fall within the realm of the systems approach to general aspects of a composite reality.

In this context then one may define an educational system as an organization of interrelated and interdependent components influencing the learning-teaching situation with the intent that each distinguishable element contributes in an essential and cooperative way to the outcomes of instruction. Thus, the characteristics and functions of the elemental variables determine in large degree how effective the composite system is in attaining stated objectives for instruction. Obviously, these elemental variables originate only in part with the impersonal domains of the disciplines and the media of instruction. The human sources of operant functions, including the instructor, students and their peers, continually interact within any given learning environment. Even though it is a subunit of the total system, the curriculum shapes the larger portion of that system in which the impersonal elements of subject fields, learning methodologies and integrative goals operate within the educational boundaries of a general system for learning at the college level.

Pattern recognition methods augment the systems approach by helping to identify empirical relationships between variable elements characterizing the system, and as such are ultimately procedural. In other words these techniques aid us in locating rules of correspondence which might have been overlooked by a more superficial examination. The consideration of "purpose" or end toward which the relationship seems to be oriented is clearly not an explicit part of the methodology of pattern recognition. On the other hand, the analysis of processes operating in a total system, whether abstract or concrete, can include the ends-in-view toward which the system is or might be directed. An educational system requires choices at many levels among various means and ends; and the system is responsive to a changing environment for learning, to an expanding knowledge base, and to shifts in social and individual values. Thus, liberal learning with its wholistic stance can be viewed as a goal-seeking system in which a greater variety of learning behavior on the part of the student is encouraged by a range of devices and instructional modes.

The two-variable mission vs. mode plots of Bruce Joyce along with the Berman diagrams in Chapter I illustrate the formalized pattern which is called a gridchart in systems analysis. The intention of the gridchart is to identify relationships between two groups of system elements designated either as operations or objects. However, the usefulness of the gridchart is extended by the manipulation or analysis of its elements through the application of preprocessing techniques of pattern recognition. A ranking among the functional elements may become visible in a given gridchart (as in Figure 5-5) or correlations of elements in common to more than one gridchart may be possible. Thus, the gridchart can introduce a measure of prediction into systems analysis when additional operations are performed with its component parts.

In the field of education systems models have been developed to describe the larger problem of instructional design in terms of operations and activities.[12] Two plans for the management of instruction outlined by Tuckman and Edwards[13] and by Knirk and Gentry[14] are representative and depict the general features in this approach. The model requires that the overall goals of instruction, behavioral objectives, teaching strategies, and media for instruction be viewed as a coordinated whole. The order for planning a complete instructional system is as follows.

A. Goal selection. A choice of confined goals which can be clearly defined and are realistic.

B. Analysis function - to include the subdivisions of:
   1. Task analysis - breaking down the general goal into intermediate objectives and a terminal objective.

   2. Task prescription - specification of the tasks and their sequencing in terms of behavioral objectives.

C. Synthesis - to specify instructional activities directed toward realization of the ordered behavioral objectives and to include alternative solutions to the problem of instruction.
   1. Prescription of learning activities.

   2. Design of evaluative methods - to be used concurrently with instruction as well as in summary.

D. Implementation of instruction - to view the instructional modes in operation, as opposed to the three planning functions (A through C).

This stage includes the review and analysis of evaluative data as well as the instructional activities themselves in order to provide feedback information for revision of the system as it operates.

It has been pointed out by Robert Fromer that the level of specification for the goal and task analysis determines whether the outcome of instruction has been an educational system or simply a training system.[14] A training system has its behavioral objectives specified for the performance of particular tasks or the acquisition of specialized skills which are occupationally and product oriented. By contrast, an educational system integrates those cognitive, perceptual, and motor skills in common to a variety of occupations and problems; and, therefore, it necessitates the specification of both process and product elements within the behavioral objectives.

At the present time the applications of systems analysis to instruction at the college level are essentially of a descriptive-prescriptive type. These are fundamentally pragmatic and qualitative even though relying upon statistical data for evaluation steps and feedback for modifications. James R. Davis has identified four distinct types of instructional systems which are applied to the classroom format of college teaching,[15] and each is derived from a different theoretical viewpoint about the learning processes. These are: (a) the cognitive strategy; (b) the behaviorist strategy; (c) the inquiry strategy; and (d) the group learning strategy. The more obvious relationships which can exist among them are suggested by the diagram in Figure 5-6; however, certain contrasts should be noted.

The cognitive stresses the effective transmitting of information or concepts which are to be the input stimuli for the learner. From the input stimuli, the student mentally selects pertinent items for inclusion in short-term memory where the information items become coded or symbolized even though a large proportion of them is quickly forgotten. More complex symbolic processes are called upon to convert the information items into a form suitable for long-term storage as memory. In the cognitive strategy the teacher is the dominant active agent in the system and the instructional format will include the traditional lecture method as well as audio-tutorial instruction. However, from the carefully organized information array, the learner selects basic features of that information through mental equivalents of pattern recognition.

The traditional lecture-centered modes of instruction have utilized elemental approaches to cognitive learning. Kozma, Belle and Williams have constructed an organizational chart for a principle-concept emphasis in which the instructor begins with a statement of the generalization to be examined followed by a review of supporting illustrations, data, analogies and explanations clarifying the whole.[16] The expectation is that the unit lecture or series of lectures on a given concept will appear as a whole system deduced from compelling arguments provided by the instructor and/or the author of printed resource materials. Obviously, in the undergraduate setting the time-frame for learning still generally places the contributions of the teacher and actions in the classroom as secondary to the out-of-class interaction between the student and the learning materials or media sources.

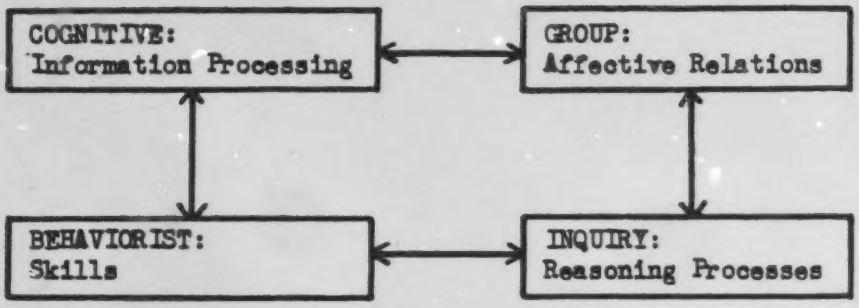


Figure 5-6. Four systems for classroom teaching, according to Davis

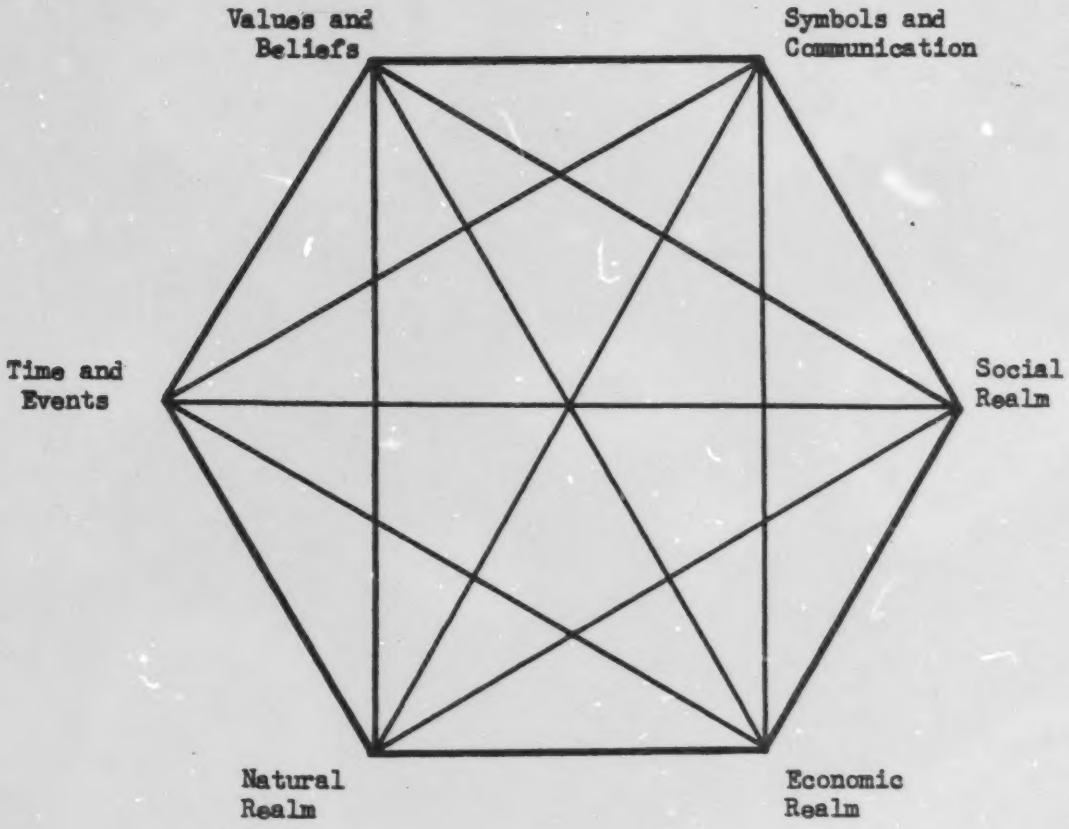


Figure 5-7. A subsystem for general education as shared experiences, according to Boyer and Levine

By contrast, instructional systems derived from the behavioristic strategy stress the precise statement of terminal objectives for learning units along with the conditions for their attainment and the specification of the criteria for evaluation of learning. The teaching modes most representative of the behaviorist strategy are the programmed, computer-assisted and self-paced instructional systems. These modes have been shown to be very effective as teaching systems for the acquisition of particular skills or techniques by the learner.

As will be noted from Figure 5-6, the group strategy is useful where the goal of learning is to examine and modify the affective behavior of the student, whereas the inquiry strategy emphasizes problem solving through the development of reasoning capacities. The latter shares some goals with the behaviorist strategy but with far less confinement and rigidity within the instructional system and learning resources. On the other hand, the inquiry system as an approach to human problem solving activity will bring into the learning system affective elements of values and beliefs. The group and behaviorist strategies rarely interrelate, however. A more general diagrammatic approach to learning in the affective domain will be deferred to a later section on models for teaching.

Another example of descriptive-prescriptive applications of systems analysis in education is to be found in a review of undergraduate curricula as comprehensive instructional systems. Such an interpretation of program planning has been developed by Clifton Conrad and has included a re-examination of the formats for general education as well as the areas of major concentration.[17] His systematic analysis is built largely upon the pragmatic outlines of curricular features proposed earlier by Dressel (Chapter II) in which special emphasis is given to the intended objectives of the curriculum. Conrad has proposed a "framework for curriculum planning" to include a sequential three-step process as follows.

Step 1 - Choosing an organizing principle centered upon one of these foci: the academic disciplines; great books and ideas; social issues; student development and specific competences.

Step 2 - Establishing curricular emphases from these continua:

a) Locus of learning: campus classroom vs. life experiential learning
b) Scope of content: breadth vs. depth
c) Origin of program design: faculty vs. students
d) Program flexibility: requirements vs. electives

Step 3 - Building a curricular structure to include: total degree specifications; concentration and general education requirements; evaluation and grading; and perimetric considerations (advising, financial, calendar).

An advantage of this model is that the planning function for the curriculum is not treated in isolation from overall institutional planning, yet at the same time it retains a primary locus on the curriculum. Clearly, organizing the undergraduate curriculum around the disciplines is not the only option in the above model. However, the usual haziness surrounding general education and liberal learning is unlikely to be dispersed by the verbiage of a descriptive planning system alone without a parallel increase in the precision

of the stated conceptual elements at a very fundamental level as these are to be employed in that systematic analysis.

One added option for planning the undergraduate instructional system in liberal arts institutions is to set aside the general studies portion for development as a subsystem having its own goals, tasks and synthesis. This is in effect the outlook adopted by Ernest Boyer and Arthur Levine in their report on general education prepared for the Carnegie Foundation for the Advancement of Teaching.[18] From a historical review, they have concluded that reforms in general education during the twentieth century have to a great extent mirrored the value shifts and major social concerns of our culture at a particular period. Their proposal which follows from their interpretation of past changes is that the next revisionary cycle for general studies should have goals focusing upon those areas of shared human and cultural experiences, with the format for the subsystem of instruction being a set of core requirements in six broad categories. These centers of shared experiences and activities are:

a) the social realm - interactions at the levels of individuals, families, groups and institutions in society;
b) the realm of communication - in symbols, visual, verbal, artistic and mathematical forms;
c) the economic realm - individuals and groups as producers, consumers, investors and participants in business and work;
d) the natural environment - the sciences at both the basic and technological levels of activity;
e) the realm of time and events - interconnecting the historical and recent past to the present and the future;
f) the realm of values and beliefs - at the individual and group levels as these shape actions and behavior as well as human purposes.

It is clear that these six areas are not isolated domains as variables in the subsystem, but rather they are a set of interconnected foci for general education. As a subsystem in itself, the possible and implied interrelationships can be identified visually from the diagram in Figure 5-7. The tie lines as well as the edges indicate that each single element (a) through (f) is related rather than being independent with respect to the remaining five components. In translating these broad area goals into specific sets of required courses and their contents it follows that such a general education plan will become a meaningful learning system only if several of the interconnections are emphasized. For example, a focus upon the social realm must integrate both concepts and factual data from the realms of the economic and values and beliefs, along with historical events, as a minimum set of interacting elements.

Obviously, the broad framework can be re-interpreted by the particulars of individual curricula in many ways with some foci being given greater weight than others; and likewise certain types of interrelationships may well have elevated roles in a general education program stressing common human exeriences. It is not unusual for the humanistic studies to have a dominant function in a set of general requirements and, therefore, the realms of values and beliefs, time and events, as well as communication will be the more strongly interdependent determinants in the curriculum through their interdisciplinary subject matter and shared instructional modes. Although the pre-

ferences of Boyer and Levine lie with core requirements as the structure for general education, the goals themselves can easily be implemented in other curricular forms. Too often the entrapping risks of a restrictive set of core requirements greatly reduce the educational benefit of general studies for the student through the imposed provincial boundaries of the specified disciplines included and too limited a perspective upon events and beliefs in relation to pluralistic industrial societies. However, on the positive side the Boyer-Levine recommendations can shift our thinking toward an explicit examination of the goals for general education as a subsystem in which the spacial chords uniting the elemental components can be ornamented and gauged.

It has become a standard practice in educational research to apply high level statistical techniques to massive quantities of data derived from a given investigation. However, the development of methods for the recognition of patterns and general structures is just as important for the construction of educational models as is a familiarity with mathematical procedures for the manipulation of measured data. For model-building in which growth functions are involved, it will usually be more fruitful to utilize such statistical tools to express the probabilistic behavior of the correlation function. On the other hand, if a mathematical model presents extreme technical difficulties or inconclusive results, it may become necessary to use a simpler and more deterministic model as an initial approximation where only semi-quantitative paramaters can be identified as descriptors of the system. At the very least, one can return to the fundamental components of the learning system and re-examine the assumptions governing those structural parts, for the varied learning processes in the academic setting imply goal-directed actions on the part of students as well as teachers. Any view of such a process-oriented learning subsystem can be re-stated in a parallel mathematical form where learning activities mean movement toward goals; and these may be symbolized either by the progression through a flowchart or by vectorial quantities depicting the major determinants of the learning system and their interactions within the learning field.

Chapter VI

PATTERNS IN LEARNING AND TEACHING

A useful analogy for the curriculum in the liberal arts is to view its ingredient parts as the pattern elements in a woven fabric. Although fabric structures can be formed from a single set of elements used in a like manner, the directional trend of the set is usually vertical and as in crocheting the dimension of width is achieved through some device of interworking with other parts of the same set. Greater versatility of patterning is possible with the woven fabric in which the warp (or longitudinal) elements are interlaced with a second set, the weft (transverse) elements, to produce rectilinear structures of seemingly unlimited types. However, variation and elaboration in woven textiles arises when the basic relationships between elements of the same set interact through crossing and re-crossing to eliminate visually their parallel positions. The spatial arrangements in fabrics composed of interlacing or interacting sets of elements can be an uninterrupted progression; and yet more alterations from wrapping or from accessory stitches expand the final structure to the point where the original sets of two-dimensional elements can be identified only with great difficulty.

In fabrics the order of placement of the threads is critical with respect to the formation of the finished textile. On the other hand, this causal bond between the plan and outcome does not dictate an unchanging system but rather a continuum of possible structural forms. The fabric's outline is obviously not instantaneous, for it is the result of cumulative interactions of directional elements or vectors. In the end the human reponse to the total structure of the fabric can be two-fold: (a) at the dissective analytical level seeking to understand the sum in terms of its functional parts; and (b) at the level of an immediate perceptive awareness of its totality. As the attention time of the observer increases, the more the second response takes on the character of the first.

The question of whether or not the textile analogy as used here is overdrawn must be re-stated initially in more fundamental terms. Can structure be identified in education as process and can it be imposed upon the totality of liberal education? Or, alternately stated, is a teleological analysis a suitable mode for inquiry into the total organization of undergraduate education?

Curriculum Structures And Learning Proccesses

Aside from any simplistic pleasure-pain theory by which learning responses might be altered, it would appear that Bruner has correctly identified one added tract in the educational experience, namely that learning serves both the present and the future needs.[1] His term for the future-directed element is the "nonspecific transfer" of learning which relates attitudes, tool skills, and concepts toward later particular problems or situations. General and fundamental knowledge provides the continuity in the educational process for nonspecific transference, and it is this aspect which is synonymous with the breadth dimension of any discipline.

The development of the learner's self-confidence requires that the totality of his responses, including not only the rational mechanisms but also the

intuitive senses, be used in the complex interplay of future acts. However, the present and future are inseparable in education as process, and the temporal experience is a continual differentiation of discursive and non-discursive impacts with the environment. For education, the essential time sequence is

Antecedent Conditions	⟶	Learning Transactions	⟶	Observable Outcomes

and it is the latter two which must be connected by a mechanism for feedback.[2] It is the contention of Elbow[3] that induction is the most effective approach for the extension of nonverbal experiences of a particular concept to the expanse of future applications of the concept.

The present emphasis upon definition of objectives and measurement of achievement by comparison to those objectives within segments of disciplinary studies presupposes that variable arrangements are possible in a subject field. The fact that no standardized pattern must be imposed or developed for approaching the discipline is not a tacit rejection of the concept of structure within the discipline itself. Rather, it is the honest recognition that it is possible to sense the complex form of the subject field through a variety of contact-response interactions between the learner and the field. As has been observed by Berman, the concept of education as process is goal-directed in itself and determines the central focus of an alternative methodology and content.[4]

Structure in a discipline exceeds the identification of general principles, for the learner's active participation in the subject field is necessary. Certainly, the participant finds that unifying concepts and principles make the area more comprehensible; however, the procedures by which the knowledge-data base for such fundamental concepts are obtained become essential to intelligibility. The deserved decline in fact-memorization need not be argued, since it is a logical adjustment to modern changes in information storage and recall. On the other hand the need for access to and production of more data entries in the resource depositories is obvious to the mature worker in the given subject field, and the educational program must include this function in its methodology. Both information management and unifying principles are among the more visible contributors to subject field structure and are future projected.

The utility role in learning is an ingredient in all educational apologies and is more easily incorporated into the present than related to the process of future-directed nonspecific transfer. Curricular forms in the most recent decades have demonstrated that newly designed programs are based on the then current values and needs with the expectation that these will project directly forward in time. Our impressions of future needs are only the most vague, and we know that unpredicted historical discontinuities will shape the future as they have the recent past.

At the present time problem-multiple-solution approaches seem to supply the only workable examples for the future-directed function in learning, and these underscore the fact that there are generally multiple determinants for physical and social events. Thus, the cross disciplinary study group forces a type of generalization function into learning which is clearly directional. For this purpose, structural forms are not nearly so much time sequences as

they are ordered segments leading to the solutions. However, to obtain that new synthetic order, related elements are drawn from the separate disciplinary structures themselves as needed. These elements must include not only principles and knowledge-data but also the procedures and thought styles as well. It is the latter which Bruner has included within the terms, intuitive and analytic thinking, as the contributors to the overall structures of the disciplines.[5] The problem-solution system gives the added extra-personal dimension to education, extending learning experiences to associative groups as well as to interacting subject areas. The term, nondisciplinary course, has been proposed by Elbow for emphasizing that this system begins with a unique but specific situation and then brings to bear the relevant aspects of the disciplines[6] in order to develop a completely new hierarchial knowledge order.

Because of the dual level responses of the learner (some time-dependent sequences and others nearly instantaneous), the structural interpretations of the disciplines given by Bruner and others have been strongly debated. Opponents of Bruner's view have cited Marshall McLuhan's theory of electronic movement and perception as uniquely different from the previous print culture and the concomitant forms. However, the views of Bruner and McLuhan are not fully divergent, as has been noted by McLuhan himself.[7] His theory is compatable with the structural approach if there is dialogue in the teaching-learning situation and a depth awareness of relationships. The latter suggests that the simultaneous perception of complete causal interactions should be sharply contrasted to the more traditional organization of learning in which functional interplay is detected by isolation of elements in a lineal form (for example the theorem-proof sequences in geometry). The tidy segmented system of the recent past did not attempt to merge the world of learning with the world of action. Electronic media stress the near simultaneity of comprehension involving almost all of the senses at once and often in an unsorted dialogue with the source. These then are the points which McLuhan shares in common with Bruner, the quality of the structural awareness itself and the mental synthesis by the learner to yield a type of comprehensive mosaic.

The world of ordinary sensory interactions seems to conform to the McLuhan view of learning. For example, the operation of a car in heavy traffic is not an ordered analysis of segments; but rather it is a time sequence formed from changing instant images requiring sensory dialogue with the situation based upon a vague awareness of cause and effect associations. However, there is the temptation to over extend the concept of simultaneity of field awareness and to universalize electronic media responses to the totality of the learning process. The nearly simultaneous awareness lacks precision of detail and can be a quite superficial mosaic, for empathy is not necessarily synonymous with depth knowledge. The time dependent analytical approach to learning certainly extends back to the non-print culture of the Greeks; and, as derivative from that culture, the developed sciences and mathematics have repeated the proof that momentary common sense based upon quite incomplete knowledge-data can be misleading or even erroneous. There is no certainty that the instantaneous and ambiguous awareness must lead to reliable knowledge or responsible consequences.

To some extent, the concept of self-transcendence proposed by Phenix is an expansion of McLuhan's field awareness as an adjunct to the dialogue of learning. As used by Phenix, the term transcendence seems to imply a duality in which the learner comes to feel that he is both the agent for knowing as well as the knower, and he becomes identified with that which he knows.[8] The

deductive consequences for the curriculum are:

(A) The primary function of education is the practice of inquiry and it is centered on the uniqueness of persons.

(B) Every learning activity should maximize dialogue.

(C) The composite curriculum will be multi-disciplinary, requiring intensive learning within fields.

(D) Exclusiveness and narrow specialization give way toward wholeness in the examination of interrelatedness of knowledge.

These consequences implied within that transcendent experience in learning are combined into what Charles Wegener has called "the reflective moment of intellectual activity" which is expected to be a mentally transforming act, i.e. an attitudinal change of a permanent kind.[9] Thus, an objective for liberal education is to create those conditions under which a self-critical and reflective (though not necessarily introspective) attitude becomes a habituating form of systematic mental activity. Mental assumptions which we make need to be examined and refined consciously and intensively as our imaginations perceive symbolically the external world of forms, languages and cultures. Clearly, in this view the curriculum provides only the framework for the initiating and facilitating of such essential processes for the learner rather than being a formalized end in itself. Such curricula should influence student behavior in the emotional and attitudinal realms as well as in the student's intellectual development.

By contract to McLuhan's view, the perceptive field of the learner is engaged in the emergent experience of transcendence according to Phenix; and it can occur through the linear print culture as well as by the instantaneous awareness characterizing electronic media.

In similar arguments Berman and Roderick have emphasized that the attitudinal disposition of the learner must be one of participation in the experience of knowledge production in the same sense that the creative artist and poet objectify personal feelings and thoughts into some ultimately visible form.[10] Thus, the physical object produced in whatever form is the result of a process in which the personal inputs include affective dimensions as factors shaping what may be intended to be objective knowledge. The involvement of the person in the process of discovery or synthesis of new knowledge begins with a very personal view of a specific learning problem even though the procedures used for its solution may be uniformly impersonal. Also, the variety of modes for knowledge production and exploration extends the range of possible imprints which will be observed on the new output from the learner as an extension from the personalized mental processes used on the problem.

The term "learning style" has been suggested by Barbara and Louis Fischer as a discriptor for the dominant personalized manner in which a student approaches learning tasks, and they have identified several distinctive types from studies of pre-collegiate classes of students.[11]

A. The emotionally involved - functioning best in a classroom environment characterized by dynamic verbal exchanges arising from strong feelings and

clashes of ideas.

B. The intuitive learner - relying upon insight and reflection more than deductive and sequential reasoning from external information sources.

C. The incremental learner - using step-by-step operations to move through new materials or subject matter.

D. The sensory learner - either relying primarily upon a single sense for ideas and information (i.e. visual or auditory) or needing several senses involved simultaneously to optimize learning.

E. Structurally oriented learner - requiring an explicitly organized learning system and environment in order to progress well.

F. The eclectic learner - capable of shifting and adapting learning strategies to the particular situation and subject matter.

G. The open-ended learner - oriented toward a free and unstructured learning situation in which the student's interests and self-direction determine the learning activities undertaken.

Although the primary learning style of the student has been established by both genetic and social-environmental factors in the early years of development and education, it is clear that these may mismatch the instructional modes of some of the teachers of the disciplines in the college setting. Therefore, it becomes necessary to examine the distinctive mental processes utilized in collegiate learning at a more fundamental level in order to effectively modify the instructional variables available for manipulation in the undergraduate learning environment. Likewise, these variations in learning styles often shape the process-environmental influences upon nontraditional learning experiences of persons outside the normal academic setting, and the special problems these pose for the evaluation process in nontraditional higher education have been reviewed critically and thoroughly by Dressel.[12]

The emphasis given by Phenix to the operational role of the learner is derived from the psychological viewpoint that genuine information requires discriminatory responses. Guilford has applied the information-discriminator function to the development of his "structure-of-intellect model" for mental abilities.[13] This model requires a three dimensional plot shown in its most rudimentary form in Figure 6-1. Each intellectual ability becomes a general skill whose development is as dependent upon experience and repeated use as upon hereditary limitations. The distinction between the three coordinates is made clear by their separation into several representative component parts.

Information Contents	Operations	Information Products
Semantic inputs	Memory	Classes
Symbolic inputs	Cognition	Units
Visual-figural	Convergent--divergent sorting	Relations, transformations
Behavioral	Reaction	Attitude changes

The Guilford model is based upon a multiple factor analysis and has been

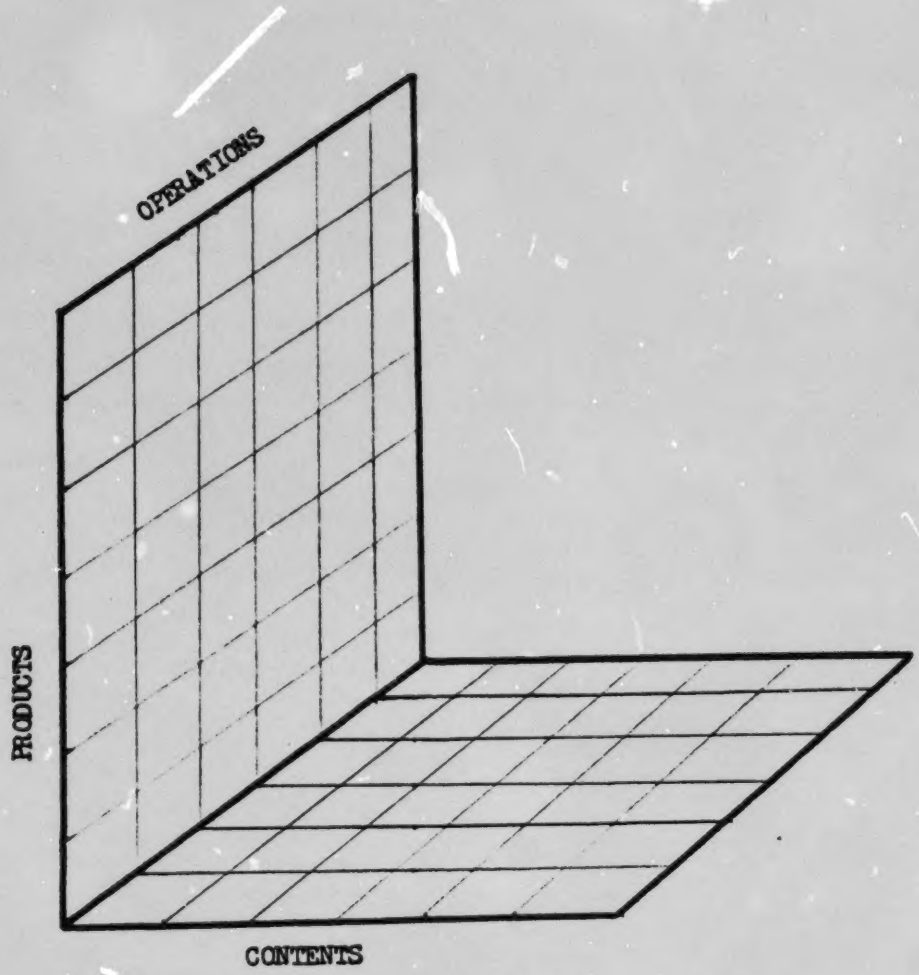


Figure 6-1. Guilford's structure of intellect model

able to identify numerous interacting variables entering into the sequential and multiple step operations involved in problem-solving. The specific operation of transformation of information in such a creative sequence is equivalent to the pre-processing step in pattern recognition; and the divergent operation is the mental analog of the pattern discriminator operating in the nonparametric mode. In addition, cognitive, productive, evaluative and recall operations are all utilized in problem-solving behavior.

The central role of memory in all aspects of learning is quite familiar to college teachers and in problem-solving memory impels the operations performed on the information contents rather than being a passive repository of information alone. Memory activity enters both into the encoding phase for processing information items for storage and into the dynamic retrieval of information from long term stores. However, the experimental findings of cognitive psychology strongly suggest that memory operations cannot be fully understood without resolving them into several subfunctions; and Reynolds and Flagg have identified a minimal set of three.[14]

A. Verbatim memory. Here it is the goal that the incoming sensory information be exactly duplicated in memory so that literal recall is possible at a later time. As a form of human memory much admired, it is an essential component of certain levels of basic learning for such items as place-names, counting, musical scores, poetry and dates of historical events. The cognitive function of verbatim memory requires both active and adaptive participation in the learning, retention and recall of verbal information contents.

B. Reproductive memory. Less significant details and superfluous information items are deleted in the processing of the incoming sensory information with the result that upon recall the person can reproduce only a synopsis of the original contents. This is the memory function we most commonly exhibit in the recall of our reading of printed material and of visual impressions, and yet it is usually more holistic or comprehensive than verbatim memory.

C. Productive memory. A synthetic or analytic function for memory is the most active operation stressed in productive memory. For this type, the sensory input content is sorted and organized in relation to already known (stored) information in order to interpret through logical reasoning and by intuitive responses the meaning of that information.

A broad range of verbal and nonlinguistic elements enter into the interpretive operations and our internalized past experiences as well as our values are major determinants individualizing productive memory functions. The recall of stored information and the inferences drawn from it then gives rise to a personalized or existential output of information products.

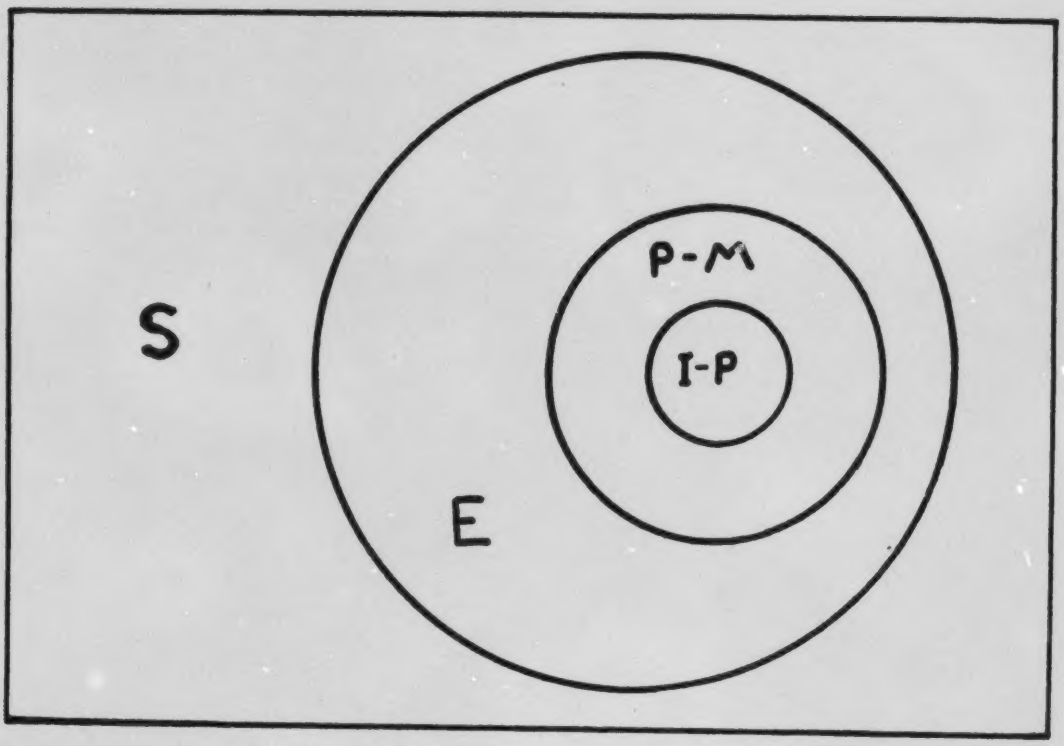
Although learning systems at the college level must activate and utilize all three memory functions, the extremely complex nature of the stimulus material forces the instructor to perform some pre-processing of that material for the benefit of the student. In general education curricula learning should use verbatim memory functions less than reproductive and productive memory. However, within the disciplines all three memory operations are continuously employed by both students and teachers. Within the disciplinary studies a high priority is often given to what Guilford has called divergent thinking, implying problem re-definition, originality and elaboration to examine a var-

iety of solutions to a simulated or real problem.

It is clear that structure for the disciplines cannot be isolated from the mechanistic complex of the learning process nor from the perceptor of knowledge. The limitations and advantages of both electronic information movement and print culture have to be assessed in order to give favorable depth insight, dialogue, and comprehension in educational processes. As long as there is progression in education, there is the problem of selection and packaging of information for instruction. Although the re-structuring of disciplinary learning may be merely a lineal re-arrangement, it need not be so restricted. The dynamics of the subject field will identify the means for continuing dialogue and inquiry, for the conceptual forms themselves undergo continuous revision and indeed replacement. In one sense the process of education itself may be one of structure-finding through whatever perceptive and analytical means are available and reliable at the time. It is a search for wholeness and continuity as well as knowledge production and depth awareness. However, the degree of structural detail needed is dependent upon the objectives and the level of sophistication deemed appropriate to the learner.

The Lewin theory of personality provides some valuable insights into such a holistic view of learning, and the Euler diagram in Figure 6-2 is an adaptation of the Lewin mapping system.[15] Here, both learning and individual behavior are determined by the interchange between the person [(P-M) + (I-P)] and the psychological environment (E). It is to the summation of the inner pair of concentric circles that Lewin assigns the "life space"; and this region depicts the psychologically differentiated field in which both cognitive and affective behavior modification occur. Because of the limitless and comprehensive nature of the physical-social environment, its boundary with E demarks an enclosure of only that part of the total with which interaction takes place at a given time, and the boundary is itself permeable and non-rigid. Likewise, the inner-personal region is dependent upon the motor-perceptual mechanisms for contact and interchange with the external portion of the psychological environment. The substructures of the personal and environmental regions as well as the resistance at boundary crossings are determinants in behavior modification, creative responses and rational thought.

In the Lewin diagram the cross-over or interaction between the social-physical environment and the learning field requires a conscious focus upon some portion of the multiple stimuli coming from the external environment. All of these stimulative events impinge upon the body senses, and the central processing of the sensory information by the brain determines whether a particular motor responsive act is needed or whether the information is to be further internalized in the I-P region. If the mental awareness arises from a conscious directing of one's attention on some particular stimuli within the external environment, the individual is then psychologically attentive. However, the attentive response may be merely a repetitive one toward a familiar set of stimuli or it may be directed toward the novel stimulus chosen from among a multitude of more familiar stimuli. Attention implies regulation and it is this aspect of the control of the learning processes which is fundamental to the linear stimulus-response teaching of basic skills. The latter uses a narrowed attention on the part of the student, restricting the focus toward very specific and pre-determined stimuli. The risk of overuse of instruction patterned upon S-R concepts is that boredom or low performance levels will result from overly familiar stimuli and instructional forms being used for ex-



S = Social-physical environment

E = Psychological environment (learning field)

P-M = Perceptual-motor region

I-P = Inner-personal region

Figure 6-2. Lewin's structural theory

tended periods of time. Repeated reinforcement for specific responses can dull interest in learning just as it does in industrial production operations.

The inner-personal region actively influences the selection, encoding and interpretation of received information as well as the structuring of productive memory and learning. Attentional mechanisms of the mind can be stimulated to respond to the unexpected and interesting in the social-physical environment through the growth and development of the brain's perceptive tools and conceptual-organizational functions. Meaning can evolve from the interactions between the memory cues of earlier related experiences and the new semi-processed information being received. Learning then becomes a generative process in which the inner-personal region imposes both an analytical and wholistic organization upon the multivariant input information.

Curriculum design, teaching methodology and subject matter can directly manipulate only the cellular distribution and interconnections involving the outer portions of the learning field (E); and to a more limited degree these can extend the interactions with the perceptual-motor region. In Lewin's model three principles--relatedness, concreteness, and contemporaneity--govern the quality and extent of behavioral interchange within the life space or learning field. His view of the dynamics of the developmental process utilizes the following field constructs which relate to process oriented learning.

A. Variety - an increasing range of facts and relationships with increasing age.

B. Differentiation - within the psychological environment and the person; and a simultaneous increase in the number of boundaries within each realm.

C. Integration - increasing organization of behavior with age. Although structure-seeking goals often require complex and indirect paths through the learning field, there can be little doubt concerning its importance in liberal learning.

Adjunctive arguments can be drawn from Piaget's theory of psychological development in which the derived educational task is to devise ways of structuring and managing the person-environmental encounter in order to accelerate the rate of intellectual development.[16] Educational objectives cannot be achieved without a proper matching of instructional procedures with the entering behavior level of the learner. Piaget's view of organization as one functional invariant describes the fact that a given mental act is a part of a continuum of such actions and as a part of that whole it bears some relationship to the totality. Thus, any cognitive encounter involves some form of mental interpretation and subsequent accommodation to the new and perceived reality. In the earlier stages of intellectual development the interactions between the self and the learning field are present-oriented. However, as that development progresses, there is a greater role for the exploration of variable ordering and for reflective thought. This shift in developmental emphasis with maturation of behavior implies a more future-directed and hypothetical exchange between the self and the social-physical environment. Thus, the curriculum must provide for instruction within the context of both the individual and the group modes in order to facilitate behavioral modification through real and concrete actions on the part of the learner. Piaget's theory is a logical but non-rigid theory of learning which generates a range of hypotheses and it is from these that instructional modes evolve. He recog-

nizes that the individual begins with a set of genetic determinants; however, the patterned outcome of a lifetime of learning is uniquely individual and unpredictable. He has identified those mental structures and activities characteristic of all persons at successive stages of development, structures which persist even though transformed by multiple interactions along the composite developmental sequence.

If the subject fields themselves have elements of structure which lead to meaningful knowledge, then cross-disciplinary interactions would be expected to yield hybridized non-disciplinary forms of thought. The functional locus for generalization and synthesis beyond disciplinary boundaries is a weft element of current liberal learning objectives. Its implementation in the curriculum has not been by random placement but by various schematics intended to optimize conceptual interplay. The very act of formulating educational goals and their deductive structures for learning is a selective process based to some extent upon value commitments, and Dressel reminds us that any attempt to isolate the cognitive from the affective domains in altered educational experiences is useless.[17] The decision-making process when applied to the learning-instructional segment of a social subsystem requires unavoidable constriction of the scope of knowledge included as well as restrictions on the freedom of action for the learner. The whole attitude we share toward the curriculum is tied directly to a value base, and a range of viewpoints reflecting this fact are represented in the review edited by Frank Jennings.[18] Our values which may give special importance to integrative and humanizing learning will govern some of our most fundamental choices and preferences as we assemble a specific learning system from among an assortment of many potential and coherent plans for liberal education. Any theory of curriculum ultimately becomes intermingled with assumptions derived from learning theory and uses in its foundation elements of logic, psychology and implicit values. In the very structural synthesis of Bruner the real world is assumed to be intelligible and the learning responses require goal identification, hypothesis formulation and testing as well as feeling, but all within a developmental mode of individual learning.

If behavior changes in the direction of more individualized learning become essential goals in liberal education, then methods stressing independent study experiences are required. Dressel and Thompson maintain that all college students have the potential capacity for self-directed academic work and that the development of this potential should be a major future-directed objective for undergraduate education.[19] Self-directed independent study projects must allow students to explore in depth and/or breadth topics not included in the regular curriculum. However, for these projects to be meaningful, they must be built upon the skills and knowledge base which the student possesses and yet must challenge without overwhelming the student. The effectiveness of the independent projects as learning experiences for the students is determined in part by the care used in planning specific and realistic goals, as well as by the quality of the guidance and supervision from the resource persons (i.e. instructors) interacting with the student throughout the course of their projects. The idealized goal for self-directed study is to assist the student to constructively master an unfamiliar learning problem with openness and yet with some degree of confidence that the strange or unknown can be surmounted and that key questions circumscribing the problem can be at the very least identified if not fully resolved. Piaget's theory of adaptive behavior underscores the fact that the learner's perception is always active,

not passive, and that mental growth means choices between alternative actions.

Bruner has observed three primary learning modes which parallel the trends in mental development and the structure of human experiences.[20]

A. Enactive - direct action involving choices and reinforcement of appropriate responses.

B. Iconic - learning from the demonstration or performance by others.

C. Symbolic - involving transformation and ordering of information, coding for inferences.

As an instructional technique, the demonstration is distinguished by showing very explicit alternatives as well as how to choose among them. This is quite separate from the enactive mode which is exemplified by conditioned behavioral techniques with their system of rewards and/or penalties. Indirect learning through symbolically coded information transmitted and modified by media is the principal mode in all areas of higher education.

As was noted at the beginning of this monograph, Susanne Langer classified knowledge symbols either as discursive or non-discusive. Larry Gross has approached the symbolic mode in an alternative manner by examining behavior and experience as well as communication and thought, for even the latter must be viewed as an activity.[21] Because of the importance of the symbolic modes in actions leading to the personalizing of experience and perception, a number of the features in the analysis by Gross apply to a process-oriented interpretation of learning at all levels.

I. Primary modes of symbolic behavior. These are identified with specific ordering principles determining the meaning of the symbol as communicated. They are not translatable into other modes and are either general or distinctive.

   A. Linguistic (or lexical) mode - verbal formulation, transmission, and storage of symbolic experience and meaning.

   B. Social-gestural mode - cultural patterns for nonverbal actions within a society and are socially conditioned.

   C. Iconic mode - perceptual and visual interaction with objects in space.

   D. Logico-mathematical mode - logical thought embodied through special signs and operations for deduction and induction.

   E. Musical mode - musical meaning expressed through a formalized code for sounds and sound qualities.

II. Derived modes. All of these are dependent upon two or more of the primary modes for their structure. For example, drama is dependent upon combinations of the first three (A,B,C) primary modes. Similarly, any creative performance in the visual and sound arts is likely to involve multimodal actions.

The major implication of Gross's interpretation for our educational efforts is that the progression of the learner in every area is dependent upon an expanding competence in symbolic modes of action at both the perceptive and manipulative levels. According to Gross, the essential contributors to that competence are:

(a) knowing the symbols and their uses in context;
(b) comprehension of coding operations and transformations;
(c) skill in storage and retrieval of coded information in a given mode;
(d) evaluative skill in order to appraise coded information or actions.

Here, the specialized use of the term, skill, includes both the generative and appreciative dimensions acquired through practice and observation. Obviously, symbolic competence can then be extended beyond simple coding and decoding acts; however, at the basic as well as the complex levels the development of skills simultaneously structures the accompanying thought and action in an almost involuntary manner. All of the learning modes, enactive, iconic, symbolic, ultimately transform consecutive and seemingly random learning experiences into knowledge through actions grounded in structured mechanisms.

Models For Teaching

As was observed at the beginning of this monograph, it is essential to recognize the obvious condition for learning inputs in the college setting: that both the students and the instructor bring an extremely wide range of prior learning experiences, actions, and procedures into the new and specific undergraduate educational environment. N. L. Gage has used the appropriate term, presage variables, to represent those prolonged academic and social experiences acquired from the past learning by the individual student which can be potentially the most important elements reviewed by an admissions representative.[22] On the other hand, it is the process variables in liberal learning dealing with teacher-student interactive behavior which occupy the attention of the classroom teacher in modifying the current learning situation in order to achieve particular anticipated educational outcomes. However, it is not always clear whether a given set of teaching variables have a necessary and causal relationship to the observed outcomes because of the complexity of learning processes themselves; and yet there is little doubt that instructor behavior and actions do influence student responses and attitudes even in classes where the presage variables for the students reflect a relatively unselected and heterogeneous student population. Deliberate teaching actions and instructional plans directed toward the alteration of the learning field of the student will delimit and indeed focus the development of the varied memory functions as well as manipulate the complex of symbolic responses by the learner in a given college level course.

Just as the shaping of the curriculum itself reflects our images of the structure of knowledge and its meaning, so also do our plans for instruction correspond to our beliefs concerning learning processes and modes. A number of models can be and have been used to describe the plurality of teaching approaches applied at various levels of education, and an extensive critical examination of them has been made by Joyce and Weil.[23] These reviewers place models of teaching into four broad classes (or families) based upon the

sources of the primary assumptions implicit in each with respect to the learner and the objectives of the process. In an order of increasing person-oriented emphasis the principal classes are:

A. Information-Processing Sources - directed toward extending the learner's capability and skill in information processing, concept identification, and problem-solving. The setting is the academic discipline and the derivative modes are deterministic.

B. Behavior Modification Sources - attempting to shape the external behavior of the learner through operant conditioning and reinforcement for actions compatible with the objectives of learning.

C. Social Interaction Sources - intended to develop the learner's ability to relate to others and improve the social environment, as well as confronting value-oriented issues at the personal and social level.

D. Personal Sources - beginning with the learner's personal reservoir of real and psychological experiences as a basis for organizing a view of reality and for providing a foundation for building an authentic personal and world view.

From a philosophical viewpoint, it will be recognized that the range from classes A to D is a shift from a materialistic-mechanistic conception of knowing toward a more existential position along an epistemological continuum. As such, the distinction between classes will not be sharp and the orientation of the teaching modes for each will show extensive overlap. In this respect the grouping of models for teaching is primarily an analytical device, but nevertheless it has a considerable descriptive and diagnostic potential.

At the college level of education nearly all of the instructional methods can be described by models falling in the first two classes, namely information processing and behavior modification, with the preponderance being in the former. Conceptually, the various forms of learning activities in undergraduate education tend to be directed toward information transfer, organization, manipulation and generation. The disciplinary orientation of our teaching gives special importance to reasoning by induction as well as deduction, extension of intellectual capacity, simulation and other strategies for thinking and for sorting our store of information. Individual sensitivity to external environments takes on the perspective of a rational experience of diversity and an awareness of alternatives, as well as the requirement to hypothesize, explain or even to predict. Thus, information processing as a starting point for structuring learning is by no means restricted to the areas of the natural sciences, mathematics, and social sciences, but is very much a part of instruction in literature, languages, and the humanities generally within the colleges and universities.

Most college teachers have some familiarity with behavior modification sources through their various trial efforts with programmed instructional materials intended for student self-instruction and remedial work. However, the broader implications of behaviorist theories for student learning have been extended by a number of educators and representative of such approaches is the work of Robert Gagné and his coworkers.[24] Gagné has expanded the taxonomy of Bloom to include five categories and when arranged as an ascending hierarchy

of learning skills, the following listing is obtained.

A. Motor skills. Manipulative and memory skills in which repetitive practice increases accuracy and usually the speed of performance of the task. Familiar examples include learning the fingering for a woodwind instrument, typing, and swimming.

B. Verbal communication. Correct word usage, reading, and general language skills are placed here.

C. Attitudinal views. The personalized disposition exercised by the student toward choices among objects or options for directed actions.

D. Cognitive skills. The modification of thought processes and modes of reasoning as in dealing effectively with limited mathematical or social problems.

E. Intellectual skills. Gagné justifies the separation of this category from the cognitive by placing special emphasis upon the learning capabilities directed toward higher levels of mental actions to include: concept definition; recognition and applications of rules for classification; discriminating selection and identification; and the derivation of higher order theories or more complex rules and relationships. These skills assume special importance in the teaching of the behavioral and natural sciences.

The above categories provide the basis for a behavior modification model of instruction in which the given system is developed from carefully formulated objectives. Gagné has used the term "task analysis" to encompass such a total planning function including the identification of pre-requisite experiences and previous learning needed for particular learning tasks as well as the specification of sequences for learning events. The five categories above provide the structure for both the classification of learning tasks and the description of the learning outcomes. By using a framework of this type, the systematic formulation of performance objective is often simpler and indeed less cumbersome than other more restricted schemes for writing behavioral objectives involved in the more complex learning sequences at the college level. Care must be used in the specification of pre-requisite learning experiences or knowledge to be certain that only essential and supportive skills are included. When the objectives for instruction are designed in relation to performance outcomes, test construction and evaluation of the evidences for the learned behavior can be accomplished in a very direct manner.

Information processing and behavior modification models are usually formulated to produce definite observable effects through specified acts, and the student is the receptor interacting with various sources of information, including the teacher. However, Joyce and Weil have pointed out that there are extended maturational outcomes inherent in these models as well as the short-term instructional effects which complicate the problem of evaluation and guidance of student progress.[23]

The initiating step in an information processing model of learning is the direction of an attentive response on the part of the student toward the incoming information. However, conclusions from cognitive psychology indicate

that the function of attention is not only one of directed exposure to the incoming information but it also serves a selector role in allocating information items within the mental processing system having a limited capacity.[25] The level of attention which we would commonly refer to as alertness will also be an important variable conditioning the allocation of the available processing capacity for information at any time; and higher attention levels are required for dealing with more complex information sources as well as subsequent complicated processing sequences (i.e. problem-solving activities). Often, it is the medium or the particular form of the instructional resources which is likely to become the major determinant in the initiating step for the information processing model. The increasing appeal of electronic media and computer-assisted instruction probably arises more from their facility in eliciting nearly total attentive responses and rapid interaction from students rather than in any uniqueness in the organizing or presenting of information.

Even though attention may serve as a control over the incoming information, it appears unlikely that attention further regulates the succeeding step in the process in which the sensory information is encoded in a more lasting form for manipulation or storage in either short-term or long-term memory. For the mature student, the operation of iconic encoding of visual sensory information becomes largely automatic in such activities as reading a printed page of instructions in which familiar language is used. However, any additional re-coding of that information into a new set of symbols more suitable for intercomparisons or concept formulation again requires an active and controlled processing of the information items. This operation of re-coding or translation is probably subject to capacity limitations associated with short-term memory or a fading of the original sensory perception through the decline of verbatim memory with time.[25] It is unclear whether the ultimate constraint on the information processing system is a limitation on its processing capacity or on storage capacity in memory, or some combination of both of them. Similarly, the capacity of the system to process new information will be influenced by the likely paths required, namely, a single linear sequence of mental operations or a branched sequence.

One way of representing the information processing source is to use a model based on the flow chart to depict the objectives, choices of actions, and the anticipated effects. An advantage of the flow chart is its exact specification of details along with illustrating the logical order in which the events and activities are undertaken. Interconnected parts of the process and decision points can be visualized in a manner analogous to the preparation of a computer program. Likewise, the mechanisms for revision of operations and their derivative outcomes can be located.

Because the main purpose of the present volume is to explore the representations for the overall curriculum, only a single example of an information-processing model will be included. (The interested reader should consult the work of Joyce and Weil for a full treatment of the topic of models for teaching.[23]) The flow chart shown in Figure 6-3 is a generalized and simplified schematic for the implementation of an information-processing sequence. In the diagram the oval indicates the beginning or end of the program, the rectangle identifies an operation (the trapezoid an input or output operation), and the diamond specifies a decision to be made. Given the instructional objectives and the student background (entering behavior), the early decision requires the choice of instructional procedures which will coordi-

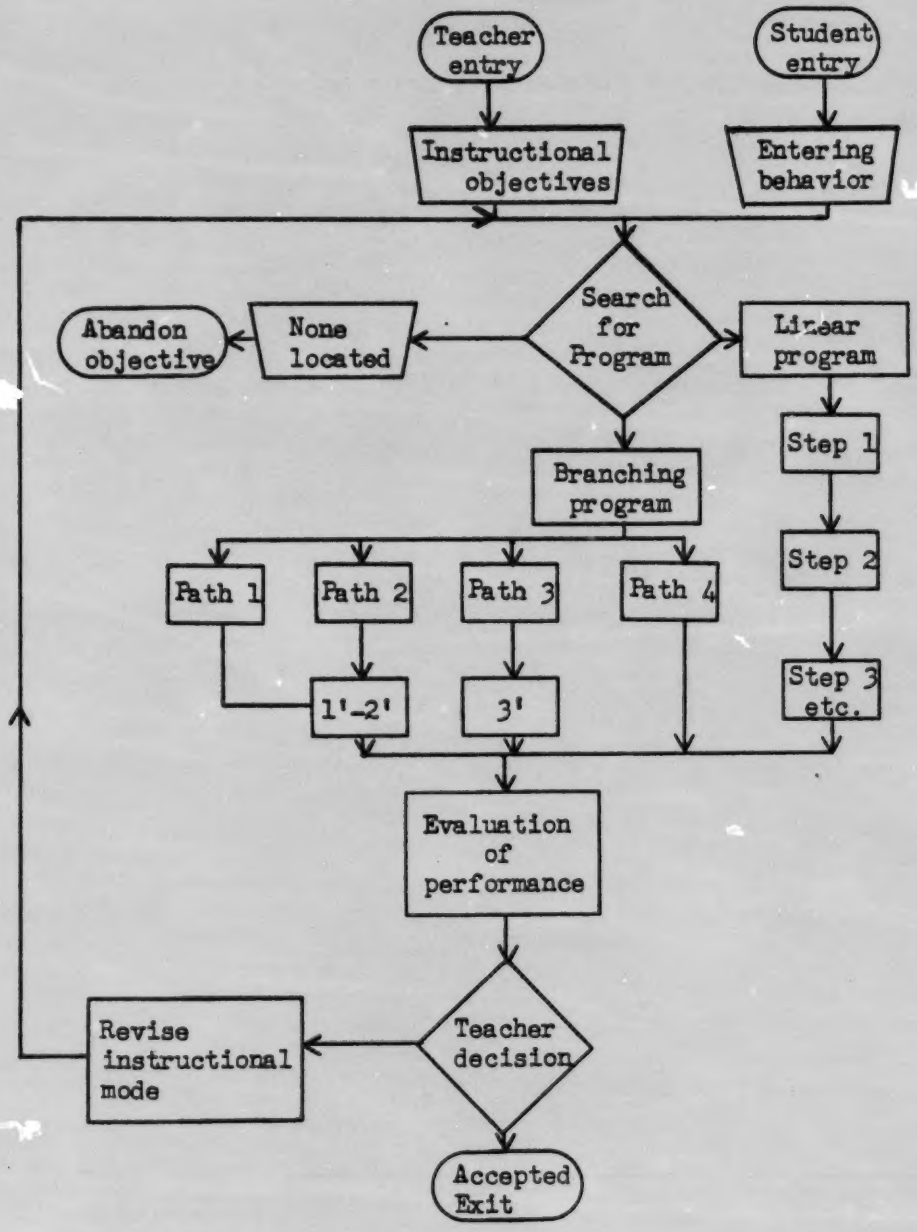


Figure 6-3. An information-processing model for teaching

nate with the objectives and which past experience would suggest. The simplest plan for teaching would be a step-by-step sequence providing student responses, correction, and reinforcement for the segments of the progression. A more complex instructional plan may be adopted in which choices among various related alternatives are made by the learner with less demand for only a single right choice. The selection of the program will be governed by the nature of the objectives, the type of information to be processed, and the educational level of the student. Although feedback cycles can and should occur at several places in the model, only the one for major revision in the instructional mode requiring a new search among the program options is included on Figure 6-3.

If one objective of teaching is the development of the learner's potential for generalizing from specific information inputs, then the simple sequential form for instruction and information processing does not apply. However, the flow chart can be used in combination with a network diagram to describe the segments in this form of teaching. It is obvious that there are varying degrees of complexity among integrative concepts and the features of several structural levels have been reviewed by Joyce and Weil.[23] The lowest level is one in which only a single and seemingly universal rule is generated from the information inputs supplied to the learner, and this form is outlined in Figure 6-4. For this conceptual level (area A in 6-4), once the rule is obtained any new and relevant information item encountered is easily handled by a binary decision of true or false. Within this conceptual rule there is no apparatus for generating alternatives; and the future decisions are unambivalent and absolute.

At higher levels of integrative thinking the learner is provided with multiple dimensional inputs of information and these can be assembled in a number of ways to generate alternate concepts. Then, the central enclosed portion (A) of Figure 6-4 must be replaced by a schematic like that shown in Figure 6-5. This new insert emphasizes that more steps are required to represent the developmental process and that intercomparisons among the alternatives will lead to a conceptual system rather than to a single rule. It follows that any positive decision upon the input of new information will be chosen from multiple responses; and, if the new item cannot be fitted into the conceptual system, the feedback option to the search step can be used. Thus, the higher level of abstraction required in the teaching of a complex generalization is clearly a part of the decision-making stage as well; and the flow chart can be adapted to the visualization of the learning problem. The implicit model is still one of information processing but modified to some degree toward behavior modification on the part of the learner.

A student self-instructional format has been applied by Gow and Yeager to the development of a "Process Model for Individualization of Curricula" (PIC), utilizing the structure of the discipline to construct a structured curriculum.[26] In this model the methodology of the discipline and particular skills are identified in order to expedite the specification of objectives and to expand concept development on the part of the student. Instructional materials and strategies are selected to most effectively implement the ranked objectives, both cumulative and synthetic (or organizational), in a manner comparable to that shown by the process-concept models of Figures 6-3 and 6-5.

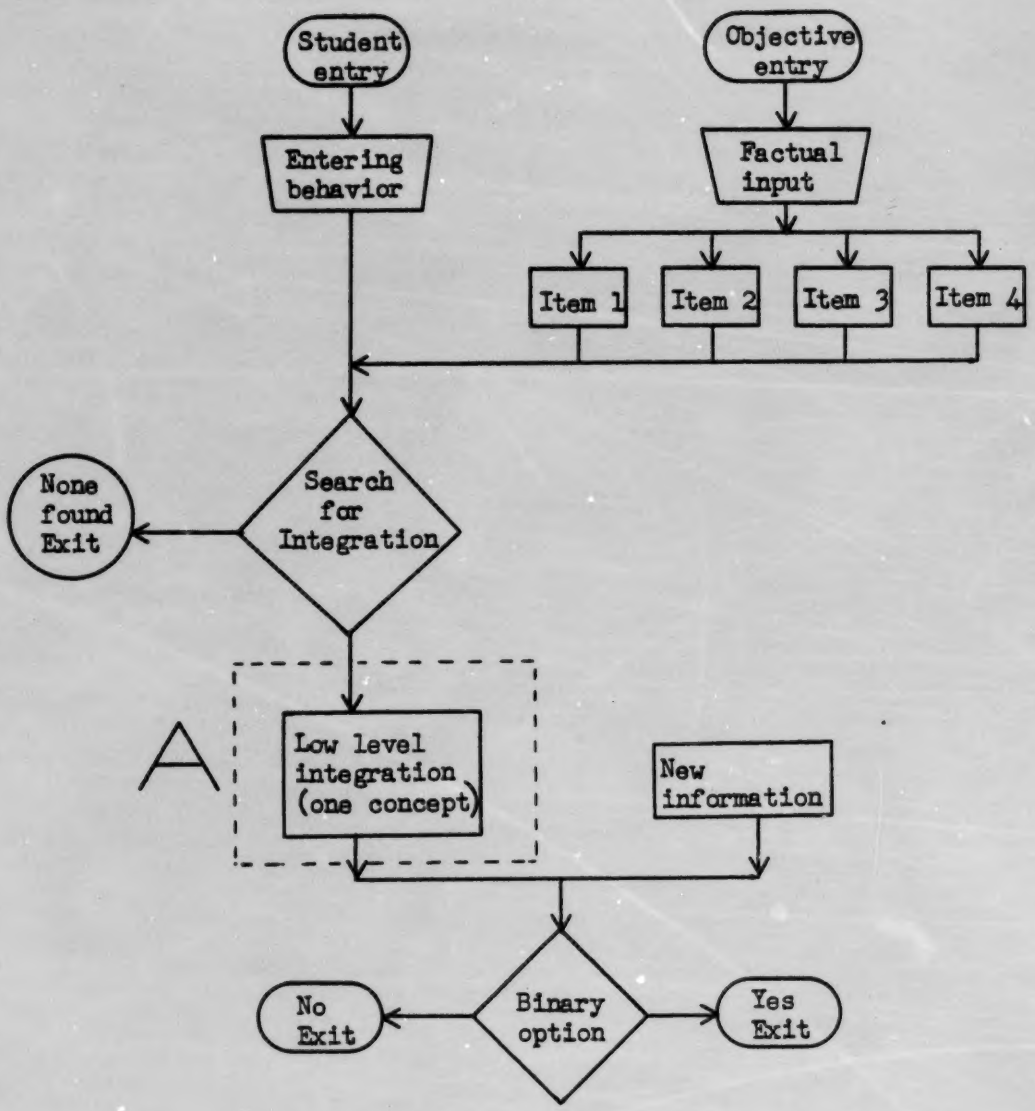


Figure 6-4. Teaching integrative concepts

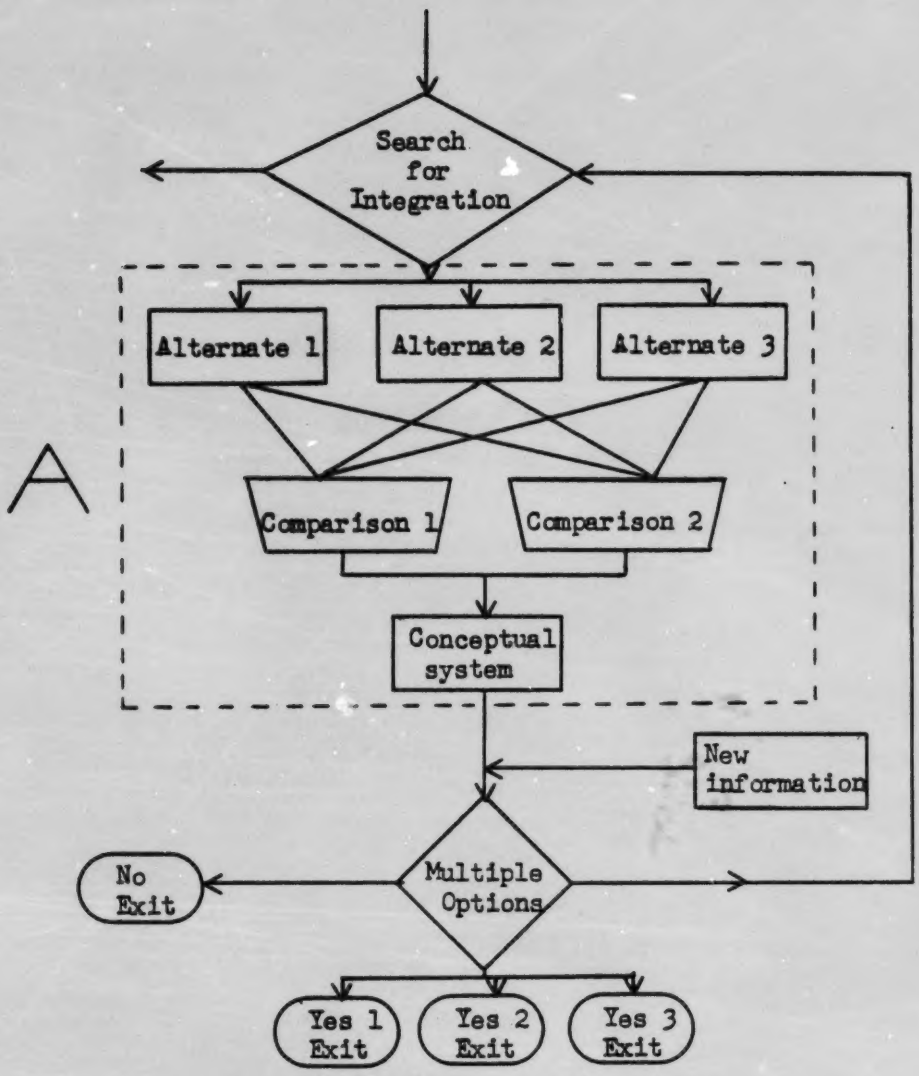


Figure 6-5. Teaching for more complex generalizations

Although oriented primarily toward the discipline, the Process Model for Individualization of Curricula is compatable with the fourth class of teaching model in the Joyce-Weil scheme, namely personal sources, and it can be extended to that class through certain modifications in its emphasis. According to Bruce Tuckman, the development of any curriculum which is to be individualized and student-centered must proceed from clearly specified behavioral objectives as a part of the goal statements for the learning process, and that development should assume that the learning experiences will be essentially sequential.[27] Then, the curriculum itself will be constructed from several defining factors including: (a) educational and occupational goals of students; (b) prior educational experiences of the student group; and (c) the psychological structure of learning processes, necessitating a multiplicity of instructional modes. Thus, the individualization of the curriculum and of instruction does not mean that the student is to be provided with programmed instruction or self-instruction as the only strategies for learning. Within a PIC system the teacher becomes a manager of the instructional system and of the learning environment; and whether or not the time scheduling is self-paced for the student may be less important to the effectiveness of intended learning experiences than the range of educational resources and teaching options available to the instructor and to the student.

By contrast to the situation in an information-processing system, a personal sources model of teaching must attempt to mobilize and alter both intellectual-active behavior and feeling-attitudal behavior. It has become customary to refer to these two ranges of behavioral traits as the cognitive and affective domains; however, most would concede that these are the terminal extremes in a continuum of learning traits. Although one tends to identify the affective domain with certain subject-matter fields such as the fine arts and music, its more fundamental characteristics of valuing, feeling, responding, and attitude dispositions are a part of personalized learning in general. The cognitive domain with its stress upon verifiable knowledge, rational comprehension, analysis, and synthesis, is the realm receiving the primary attention in any information processing model for teaching. Thinking and feeling are ultimately intertwined in all levels of individual learning, even though one or the other may be suppressed at a particular time or in a given situation.

Because the affective and cognitive domains appear to have comparable hierarchial orders for mental processes operating between the input and output of learning, Frank Williams maintains that a synthetic dualism must be formed between these domains in order to stimulate truly creative activity by the student.[28] One simple way of representing the parallelism required by this approach to the personal sources model of teaching is shown by the flow chart in Figure 6-6. In terms of student behavior similar operational stages can be identified between the initial input stimuli and the various decision points and one can recognize that the final creative outcome bears the personalized imprint of the learner. Also, the blending and intermingling of the affective with the cognitive is required at various levels in the scheme if attitude changes on the part of the learner are to occur.

Williams has built upon the Guilford three-dimensional structure of intellect model to emphasize affective-cognitive relationships in all subject areas.[28] The original coordinates -- contents, products, operations (Figure 6-1) -- have been replaced by the three dimensions of subject (curriculum), student

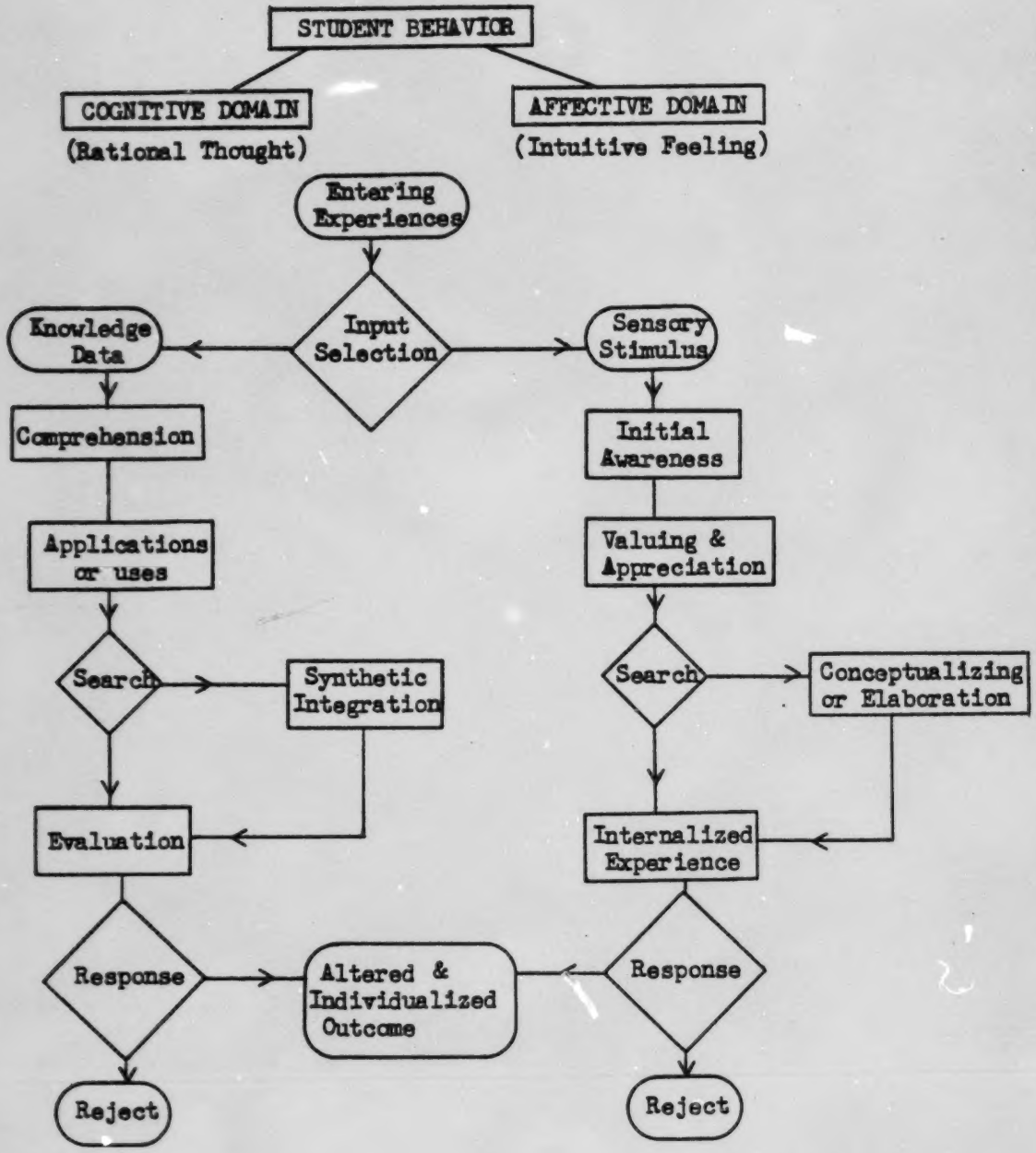


Figure 6-6. Parallel patterns for the Personal Sources model of teaching

behavior (cognitive-affective), and teacher behavior (strategies). The specific student behaviors are stated as objectives and, when interactions with some eighteen teaching modes in the matrix are allowed, a high multiplicity of interconnections can be depicted.

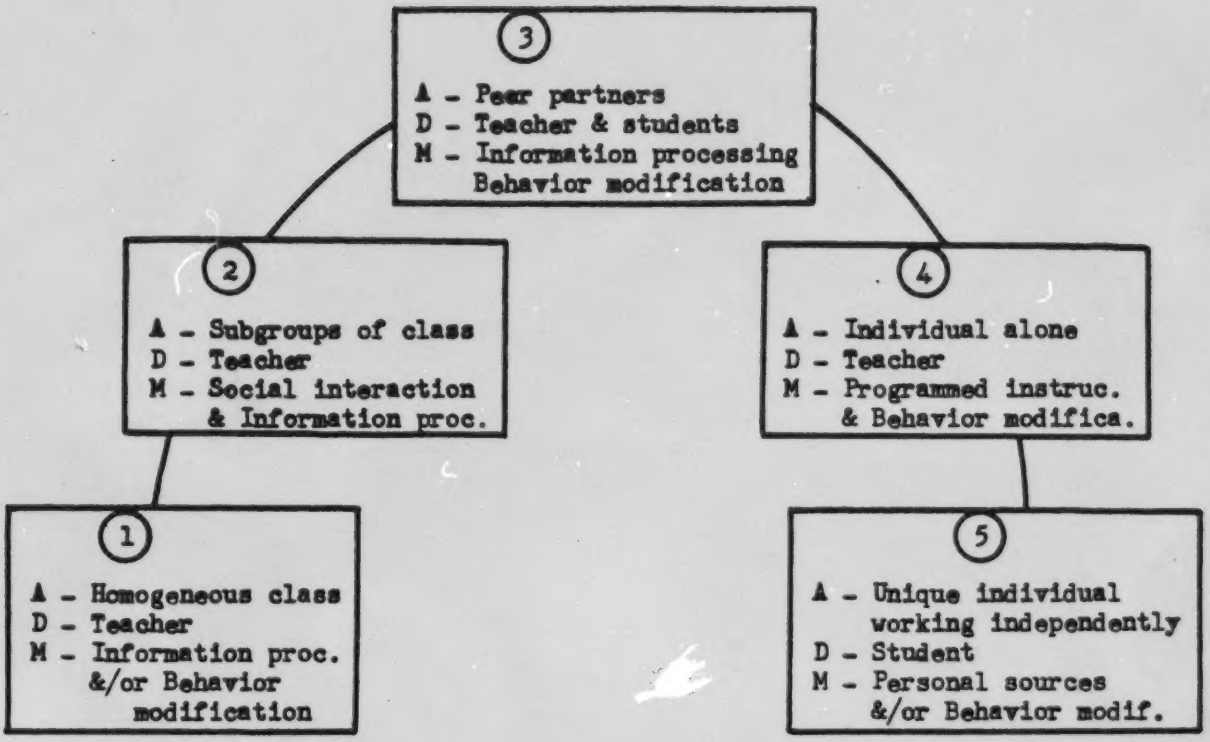
Although there has been a shift among college and university teachers toward greater individualization of instruction, so wide a range of instructional approaches have been included under that label that the fundamental elements in common to the many plans may not be clear to the uninitiated. If one risks oversimplification in definitions, the minimal characteristics of individualized instructional systems are: (a) recognition and assessment of individual student differences with respect to experiences, abilities, and interests; (b) development of individual and/or group goals for learning and the anticipated levels of achievement; (c) selection of suitable learning modes, materials, and tools which match the individual learning style of each student to the particular task; (d) regular monitoring of each student's progress and providing help as needed to reach the stated level of mastery; and (e) to some extent scheduling the specific tasks within a flexible time frame in recognition of the empirical fact that within any classroom students learn at different rates. In brief such a system recognizes the uniqueness of each student and adapts to this condition by developing non-uniform plans for reaching the educational goals while still holding to the expectation that for each successful student standardized levels of mastery will be reached and verified.[29]

The distinctions between some of the forms of individualized instruction can be clarified with the aid of the continuum in Figure 6-7. In the more formal systems which use a full range of instructional technologies there is the rigid sequence; diagnostic testing $\longrightarrow$ prescription or selection of the program $\longrightarrow$ assessment by post-test; and the teacher is the manager-director or guide of that formal program. However, other modes of individualization of instruction which are in use have been summarized by Glen Heathers from the perspective of what the student does,[30] and some of these modes can be located on the curve in Figure 6-7.

Position 5. The student engages in largely self-directed study with the instructor serving as a guide or resource person only as needed. In this case different students work on different tasks with different goals, and it is exemplified by the truly independent study project. However, criteria for the assessment of mastery within this mode are the most difficult to establish.

Position 4. Teacher-student interaction is more frequent here for all phases of goal selection, instructional techniques, and multichannel evaluation. Familiar learning plans (programmed instruction, audiotutorial sequences, etc.) allow different students using a plurality of packaged materials to pursue the same goals; and performance levels are easily standardized.

Position 3. Different students undertake the same tasks but by means of the more flexible one-on-one tutorial situation among peers as well as with technical hardware and pre-packaged resources. This position inserts the social dimension into individualized instruction as an antidote to the isolation and the tendency toward self-centeredness which may be observed in positions 4 and 5.



Code: A - Assumption about students
D - Determinant of the course content
M - Model for teaching (Joyce & Weil)

Figure 6-7. Continuum of group vs. individualized instruction

Position 2. In the group-centered mode individual work occurs within a setting where direct interaction and sharing with peers can lead to clarification and unpredicted insights. Problem-solving goals in the social sciences, humanities, or art studios are adapted to the group mode more easily than the skills development objectives in languages or symbolic communication.

Position 1. In addition to the traditional teacher-centered classroom situation this mode includes the team-teaching variations as well as the structured seminar guided by the teacher or adjunctive lecturers.

Clearly, the underlying principles required for the mode of individualized instruction are to be found within the numerous empirical studies of student learning behavior at various educational levels in the schools. A minimal set of three fundamental conclusions from such studies which justify greater individualization of instruction have been summarized by Bloom.[31]

A. There are effective and ineffective learners in any subject area as observed from the results of numerous evaluative tools.

B. There are major variations in the rates of learning with any group of students; and with the needed time and assistance the range in the final educational outcomes by the members of the group can be narrowed.

C. Favorable learning environments tend to raise the level of learning of all students in the group as well as increase the learning rate and motivation for attempting subsequent learning tasks. Parallel to this increased learning effectiveness by the students in the classroom is their improved emotional well-being and their greater self-confidence.

The overarching concern with all attempts to individualize the modes of instruction must remain the improvement in those learning experiences directed toward objectives which can be specified and the resulting levels of attainment evaluated. Normally, these objectives center upon knowledge comprehension, the analysis-synthesis approach to concepts, or applications of particular skills and principles when the instruction emphasizes cognitive learning.

In any instructional system one hopes that there is a reasonable matching of the learning objectives with an appropriate content, student learning styles, and media for conveying information. Such an optimum mix for the total system has been called "the congruency model for implementation" by Kozma, Belle and Williams.[32] However, at the college level one is fully aware of the dominance of the teacher-oriented instructional format as well as the student expectation that this will be the usual situation. Likewise, by the time the students have completed secondary schools, their individual learning styles are well developed ranging from the very dependent to the independent in terms of individual learning preferences, and from the competitive to the collaborative with respect to their group learning behavior. Major changes in learning style come only with great difficulty for many students in the college setting; and under such circumstances the instructor's organization and analytical skills alone are not sufficient to initiate useful changes in student behavior. Rather, the instructor's rapport with the students as individuals as well as personal enthusiasm are critical to initiating alternative learning styles on the part of the students, particularly

within the general education segment of the undergraduate curriculum.

The learning modes and teaching objectives for liberal learning make up the fibers in the total curricular fabric and in themselves they seem to possess structures amenable to model construction. Just as individual fibers can have differing specifications in terms of color, composition, plies and twist, so also are the microelements in learning and teaching collated by an extraordinary range of descriptive variables. However, the extreme complexity of the total problem of teaching should not deter the search for the rudiments of structure in the simpler learning systems which we employ empirically in the classrooom.

Chapter VII

PROJECTIONS BEYOND HYPERGRAPHIC MODELS

So far in this monograph the reader has been invited to examine a number of nontraditional ways for representing the liberal arts curriculum and its determinants. In this section we will pause to consider a few current trends in the practice of program development in the colleges and then to enlarge upon a few of the earlier techniques for modelling by reviewing some of their potential quantitative applications. As has been observed before, the primary intent in this essay is to employ visual and diagrammatic models to represent and to clarify various aspects of the processes and forms for liberal learning. Attention has been given to explanatory and structural relationships between essential variables and in several instances to the predictive implications of the models as well.

Comments On The Present Condition

With respect to program alone, the liberal arts colleges are faced with the problem of the management of a complex set of diverse curricular components in some manner which will project their individualized objectives. Obviously, this planning function must extend beyond the fractional disciplinary units toward a greater educational cohesiveness than is possible in the larger public universities and colleges. The present condition is one in which older models of liberal learning seem no longer to apply, though the reasons for this are not always made clear. However, the more serious problem is that our terminology is sufficiently shopworn and imprecise that neither effective planning nor realistic goal selection is taking place.

In spite of the shift in current concerns of both faculty and students toward the academic major and career specialties, most liberal arts programs have retained some formalized pattern designated as general education. It is the contention of D. Richard Little that a general education segment can be continued only if there is a reforming of its philosophical basis in terms of the uniqueness of its knowledge sources and their outward forms.[1] He argues for the position that general education cannot be identifed by particular subject fields, though it has a subject matter of its own which must pertain to all members of the student group. The creation of the former "ideal graduate" variously labeled as the educated man, educated elite, or cultured leader, is to be replaced by the representative student who will live in a world of impulse, memory, change and human creations. As a portion of the collegiate educational experiences of such a student, general education should have three fundamental dimensions according to Little.

A. Historical perspective - the preservation and appreciation of the major intellectual accomplishments of humanity.

B. Contemporary world - awareness of present-day problems and the conditions needed for the continuing existence of organized social systems.

C. Enrichment of understanding - extending beyond facts to creativity and values.

One curricular consequence of this view of general education is that the courses in the general program are divorced from the career-oriented majors and their pre-professional or professional stances. Little maintains that only through this isolation of general education can its special domain of contemporary society and the historical development of civilizations be assimilated by the representative student. If one accepts this viewpoint, then no comprehensive model for the curriculum as a whole is required. A model for the general studies portion might be approached either as a triangular vector pattern or as a square submatrix; and the planning of the disciplinary majors would remain a fully separate consideration.

A contemporary illustration of the application of Little's dimensions for general studies in a specific course other than the traditional humanities is one given by Robert Heinshohn under the title "General Education in Technology".[2] Here, the case study approach is used to examine certain features of technology, including concepts governing the operation and design of various devices, along with human needs viewed as technological problems, and technology as a modifier of social values. The fundamental assumption is that a clear distinction can be drawn between science and technology with the latter being identified with both the development of the design and the methods of production as well as the useful end-products of manufacture. The general education role is served by utilizing the bipolar tension between the technological processes and implicit goal-directions of such processes, and their designers values. However valuable a particular "General Education in Technology" course may be for students, it is placed beyond any specific major field within the curriculum and is populated for the most part by students outside of science and engineering areas in arts degree programs. The goal for such a course is to devise a truly interdisciplinary subject matter.

The complexity of the learning process and knowledge structure requires a more detailed approach to models for such multivariant systems than has been customary. The models based upon vectorial alignment proposed earlier allow some structural insights to be visually symbolized. The vector models so far examined depict different program patterns adopted by liberal arts colleges in the past seventy-five years. In each of these applications the overall curricular structure was seen to have certain characteristic emphases. As models, each diagrammatic representation of the specialization vs. generalization tension contains very specific limitations, some of which obscure important secondary structural features. Contrasts of philosophical assumptions become clearer, as is well illustrated by the comparison between the triangular and rotating disk models.

Deductive consequences of particular models cannot be ignored, since in some instances these imply that the generalization function is not simply a summation of parts, but rather that a new hybridized interaction across bordering fields is possible. In the case of the matrix model the S and G vectors can project intersystem crossings in which the pattern is changed completely in its outward form. This effect is similar to the production of diagonal patterns in woven fabrics by re-positioning of the rectilinear set of warp and weft elements.

Even for those situations in which a comprehensive re-structuring of the whole curriculum is neither possible nor desirable the application of analytical models to disciplinary or departmental units can provide clarifying sug-

gestions for program development. Such planning methods are particularly suited to those current instructional programs which cannot be directly packaged within a single traditional discipline, as is illustrated by the specialty in the environmental sciences. It is true that the environmental dimension is now included as a subordinate element in several of the basic sciences (botany, microbiology, nuclear physics, organic chemistry, etc.); however, the development of expertise in environmental evaluation and management requires a non-traditional and highly coordinated educational plan containing many cross disciplinary exchanges. Because environmental studies are primarily mission and problem oriented and lack a single unified subject-matter, it is usually not realistic for a smaller institution to establish a separate academic department within its faculty to concentrate exclusively in that area. Yet, the larger dimensions of generalization required by environmental studies make them compatible with the philosophical stance of many liberal arts institutions.

If a separate disciplinary status is not to be assigned to the environmental studies field, then the development of a teaching program in that area can be approached from either the pluridisciplinary or interdisciplinary viewpoint (i.e. Figure 4-5). In order to work from either position it is necessary to define the scope of the environmental considerations in general terms before the relevant disciplines, concepts, and methods impinging on these can be identified. The fundamental elements entering into this definition of field are given in Figure 7-1 along with the disciplinary sources.

As a region of interfacing between science and society, the form and practice of environmental science bears some resemblance to the equivalent functions in medicine and the health sciences. Each draws heavily upon the principles and information base from the fundamental sciences; each has a problem-solving emphasis; and each must be able to identify the perturbed as opposed to the "normal" condition (i.e. illness vs. health, or polluted vs. unpolluted ecological system). With this analogy the training of a worker in the two areas starts from a breadth of general knowledge, skills, and concepts, and from these, new synthetic general principles evolve for delineating the problem-solution sequence in a transdisciplinary manner. The unique conceptual base for environmental science incorporates the following descriptive principles.

1. There must be quantitative and exclusive distinctions between an unpolluted and polluted environment.

2. The hydrosphere, lithosphere, atmosphere, and biosphere are all interdependent systems involved in material exchanges.

3. The chemical form of an elemental substance determines its toxicity and its biological effects in the environment.

4. Data reliabity for environmental contaminants is limited by both the methods of detection and the sampling procedures.

The multiple-concept modular form of instruction is an appropriate mode for initiating such an interdisciplinary area of study and the submatrix curriculum model can be readily adapted to it in a manner like that given for the natural sciences in chapter 4. A simple approach to the identification of modular elements is demonstrated for two instructional units in Figure 7-2. From sequential item tabulations of this form, one may go either directly to

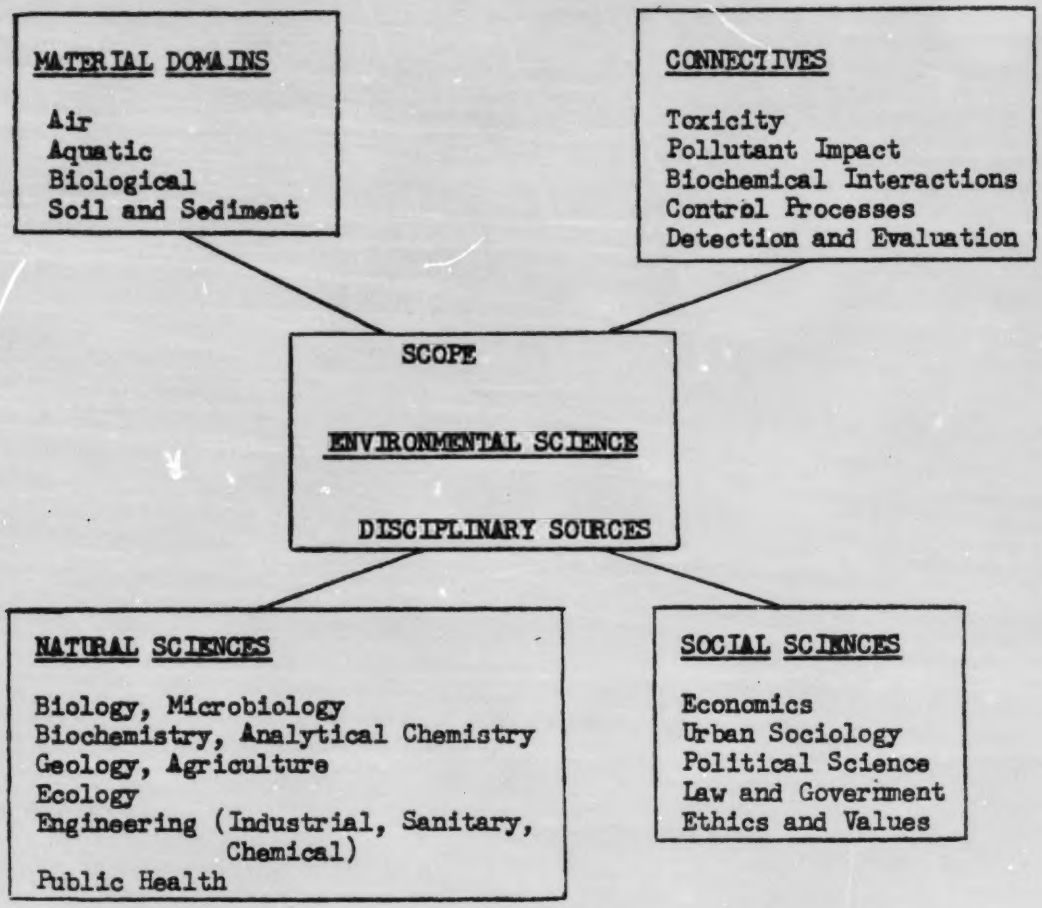


Figure 7-1. Interdisciplinarity within environmental science

Unit I. The Atmosphere As A Gaseous Environment

A. An Atmospheric Profile
B. Air Pollutants - sources and effects
   1. Particulate pollutants
   2. Gaseous pollutants - oxides of sulfur and nitrogen, ozone, hydrocarbons
   3. Smog
C. Monitoring the quality of the atmosphere - instrumentation and results
D. Exchanges between the atmosphere and biosphere
E. Legal requirements and optimum regulation

Unit II. The Hydrosphere As A Liquid Environment

A. Water resources of the earth
B. Properties and impurities in natural waters
C. Water pollution
   1. Municipal and industrial pollution
   2. Thermal pollution
   3. Detergents and organic pollutants
   4. Metallic and nonmetallic contaminants
D. Water to drink
E. Water purification
   1. Dissolved oxygen and the BOD
   2. Wastewater and sewage treatment
F. Water testing and quality evaluation
G. Moral and legal dimensions of water management

Figure 7-2. Two modular units in an environmental science program

the construction of behavioral objectives for each modular unit as a microplanning function or move toward the incorporation of these units as entries in a complete submatrix as a macroscale plan for the environmental sciences field within a curriculum. At this point it is clear that there are a number of options among modeling techniques which can be applied to curricular problems at the departmental as well as the college-wide level of organization.

No single model can be expected to be ideal for the description of any real process as complex as liberal learning. As is well known in the physical sciences, the simplest visualization of a dynamic system may be too inaccurate, and yet more reliable mathematical representations may sacrifice the necessary ingredient of fundamental understanding.

The types of models examined thus far are sufficiently simple so that specific examples of past and present curricula approximating them are easily found. It can be argued with considerable justification that this fundamental approach cannot be generalized beyond those programs which have been associated with the traditional liberal arts institutions; and, therefore, the implied value-based assumptions concerning liberal learning are too limiting to be suitable for more future-oriented programs. Nevertheless, all undergraduate institutions, either as separate private colleges or as individual schools within a public university system, must continue to operate within at least vaguely defined sets of educational objectives; and effective management requires a rational matching of educational philosophy, goals, and instructional programs. Exceptional learning environments even in colleges having strongly discipline-centered curricula are not random assemblages of instruction factors. Any curricular structure has a time-dependent rate of change curve and its future-oriented projection can be at best only a most tentative one.

As noted by McDaniel, curricula at all levels of education must be responsive to a changing social and physical environment.[3] Population and its changing age and geographic distributions, social and technological innovations, and shifts in value priorities all impinge upon both the fabric of the curriculum and its instructional modes. Attitudes and basic skills are major ingredients in humanizing learning for its future dimension, since a future-oriented education assumes that the individual can accommodate or will react to projected changes within human society. The task for the curriculum planner is to distinguish between those process elements in education which exhibit a very slow rate of change over the lifetime of the learner and elements having a rapid change rate. The micro-objective then is that the individual learner may be equipped to participate in the shaping of the future social and personal environment rather than being forced to be passively manipulated or merely overwhelmed by a cultural system.

Although by implication all current higher education is in many respects future-oriented, it should be clear that the fundamental stance required of both the instructor and the student is one of viewing the disciplinary spectrum as a series of interrelated parts and not as isolated segments composed of highly specialized fields of study. Thus, their perspective need not be one of a single rigidly pre-determined future, but rather one of openness to several alternative futures of global magnitude which will be decided by human choices as well as by seemingly chance events created by specialists. Human experience demonstrates that vast differences exist between many aspects of the present compared to the not-too-distant past; and yet there are always identifiable es-

sential connections between the past and the present. Both problem definition and problem-solving methods on a regional-global scale will dominate the future evolution of human societies to an extent not found in the past century, and a major educational task must be to help students to conceptualize on a macro scale and to logically analyze events, actions, and alternatives within an acceptable system of values.

The instructor will continue to be the major determinant in setting the style of instruction as well as the content of individual courses within the future-oriented curriculum. For such a teacher-initiated learning system, there appear to be three alternate strategic roles which the instructor may adopt; and these have been defined by Ronald Hyman as follows.[4]

A. The Presenting Function. Either personally or through some mechanical arrangement (as a textbook, selected readings, audiovisual media or computer program) the teacher chooses the information and concepts to be transmitted to the student. An expected outcome is that the student will learn to generalize from the specific information inputs or vis versa, using appropriate symbolic modes. The instructor remains dominant as the organizer and evaluator, and in its simplest form as the lecture-recitation-laboratory structure, this strategy is by far the most common role for the college and university teacher. Aside from tradition, this role and its minor variants are most easily adapted to the teaching of large numbers of students having assumed fundamental learning skills, reasoning ability and motivation.

B. The Enabling Function. Students engage in a problem-solving activity, either individually or in small groups; and the teacher assists the students or makes suggestions at various stages of definition, hypothesis testing, analysis, etc., but only as needed. As much of the activity originates with the students as possible with the teacher's role being as a guide extending to the final stages of the development of generalizations and/or evaluation of the solution. This strategy is best exemplified by the undergraduate independent study courses and in many instances by undergraduate research projects. It assumes adequate student motivation to undertake the risks involved in problem-solving activity in which the final reward may range from frustration to some intrinsic satisfaction at the personal level. Also, it assumes that serious deficiencies in the student's skills and concept bank which become apparent blockages to progress can and will be remedied before terminating the projected activity.

C. The Exemplifying Function. In this strategy the teacher engages in particular activites which the student is to interpret as the model behavior that will ultimately be imitated. Although it is usually adopted as a means of teaching skills, the values or beliefs of the teacher are implicit elements which are also demonstrated in this mode. Oral instruction in foreign language given by the teacher or by tape library illustrates this role as well as the less verbal teaching in studio courses in music, sports and in advanced science laboratories. Thus, the college teacher is actively attempting to motivate by personal example, showing a skill which will have both immediate and future use. Evaluating the student performance clearly assumes that the quality level of performance by the master teacher is the ultimate reference standard against which student effort is to be compared.

Whatever functional role the teacher adopts as a strategy, it is the in-

structor who sets in large degree the general climate of the classroom, studio, or laboratory environment. The encouragement, support, or simple acceptance which the student and teacher share may determine in the end how effective a prescribed form of instruction has been in reaching the stated educational goals.

Quantifying Implications

Most of the techniques which have been examined in this monograph have been formulated as generalized models, and in several instances these have been illustrated by selected institutional programs which have particular emphases that are compatible with a specific model. As one undertakes the reshaping and refining operations needed to convert a diagrammatic model into a more quantitative structure, careful attention must be given first to the identification of essential variables in the model and their numerical specification and, secondly, to mathematical operations or equations connecting the dependent to the independent variables. However, if we were to fix our attention solely on the quantitative predictions as outcomes for evaluating the models, we must not overlook that possible occurrence in which two quite different models may generate very similar predictions.

As one examines quantitative or numerical relationships which are implied in mathematically based models for educational processes, the initial problem then is to transform the mathematical function or symbol into an appropriate number scale or numerical measurement. However, it is important to recognize that the term "quantitative scale of measurement" is broadly applied in the social and natural sciences to include several different and mathematically non-equivalent usages. Fred S. Roberts has classified measurement scales into five fundamental types with respect to the form of the transformation required to convert a given symbol into a number.[5]

1. Nominal Scales. These involve the simple numbering of items as a one-to-one correspondence in which the objective is to keep track of items in the sense of an identification tag for future reference. For example, social security numbers or license numbers are of this type and convey information which is limited to the number assigned and to the identification of the number holder as a member of a set or subset. Thus, nominal scales can be used for the designation of specified locations or items in Venn-Euler diagrams.

2. Absolute Scales. Here the mathematical transformation is the operation of the identity, illustrated by the sequential counting scales which are used repeatedly by mathematicians in representing such things as the dimensions of polygons, solutions to polynomial equations and values for trigonometric functions of particular angles. The anticipated outcomes of probabilistic models of learning discussed in chapter 3 are expressed on an absolute scale.

3. Ordinal Scales. Where a comparison of the relative magnitudes of the homogeneous functions $f(x)$ and $f(y)$ leads to an ordered set of numbers, the required transformation is: if $f(x) \leq f(y)$, then $x \leq y$. In many instances one may be able to determine that one quantity in a series is greater or less than another and there are numerous examples of ranking sequences of this type used in educational models. The order of placement of points along a continuum and the educational mission vs. mode plot of Figure 5-5 represent functions involving ordinal scales.

4. Ratio Scales. In this instance the transformation of the function f(x) to a numerical measurement is by the simple proportion: $f(x) = a\bar{x}$, where $a > 0$ defines the value of the proportionality constant. For all ratio scales, higher numbered values are related to lower or defining unit values by the constant, a. Many scales used for physical systems are of this type, i.e. time intervals, thermodynamic temperature, and work, as well as consumer price index numbers in economics and other normalized and relative statistical data.

5. Interval Scales. The transformation to a numerical scale is made by a linear equation of the form: $f(x) = a\bar{x} + b$, where $a > 0$ is again the specification on the proportionality constant and b the linear intercept which may be positive or negative. (Obviously, for the special case of $b = 0$, the interval scale reverts to the ratio scale.) Various forms of linear regression treatments of statistically significant information are in effect establishing an interval scale for the empirical data derived from educational research.

It should now be clear that any numerical uses of vectorial parameters to analyze or interpret educational models require data which can be expressed by ratio or interval scales. On the other hand, where such high level data are unavailable or unlikely to evolve, ordinal scaled information can often be used to derive semiquantitative conclusions from less precise models. As noted earlier, simple systems of requirements like various area and core distribution plans assume an additivity among the credits to be accumulated, and the components of that summation in general studies are easily represented by a nominal scale. Also, the directional character for the general courses is less important than their magnitude within a distribution format; and therefore, scalar quantities and an ordinal scale can be substituted for vectorial specifications in quantifying that set of requirements.

Even though the descriptive aspects of the various models have been stressed, several of these can be extended to semiquantitative conclusions as well. For example, the simplest interactions of the generalization--specialization vectors depicting the total liberal arts curriculum as in Figure 2-1 can be treated numerically. The right-angular alignment of the G and S vectors represents the greatest philosophical contrast between the functional roles for general education and specialized studies among the linear vector models examined; and that resolution of the two curricular forces emphasizes the quite different objective for each as contributors to liberal learning. As a starting point for expanding the model, one can use the number of credit hours in general education as a crude measure of the value of the G-vector in the total sum required for the B. A. degree, and then the balance of the credit hours are accumulated in more specialized studies. For the most representative total of 124 credits, the portion for general education commonly falls in the range of 40 to 62 credit hours. It is instructive to consider the effect of this specific variation in the required generalization upon the resultant for the G and S vector interactions, and this influence is illustrated by the vector diagrams in Figure 7-3. The noteworthy conclusion from these numerical examples is that increasing the G-vector by 50% (from 40 to 60 credits) changes the resultant by less than 6%. Therefore, in contrast to our usual unexamined preferences for an idealized distribution of credits between general education and specialized studies, the numerical analysis suggests that shifts within that normal range have a very minor impact upon the resultant. It is only where the variation is more extreme (i.e. reducing the G:S ratio to 20:104) that the

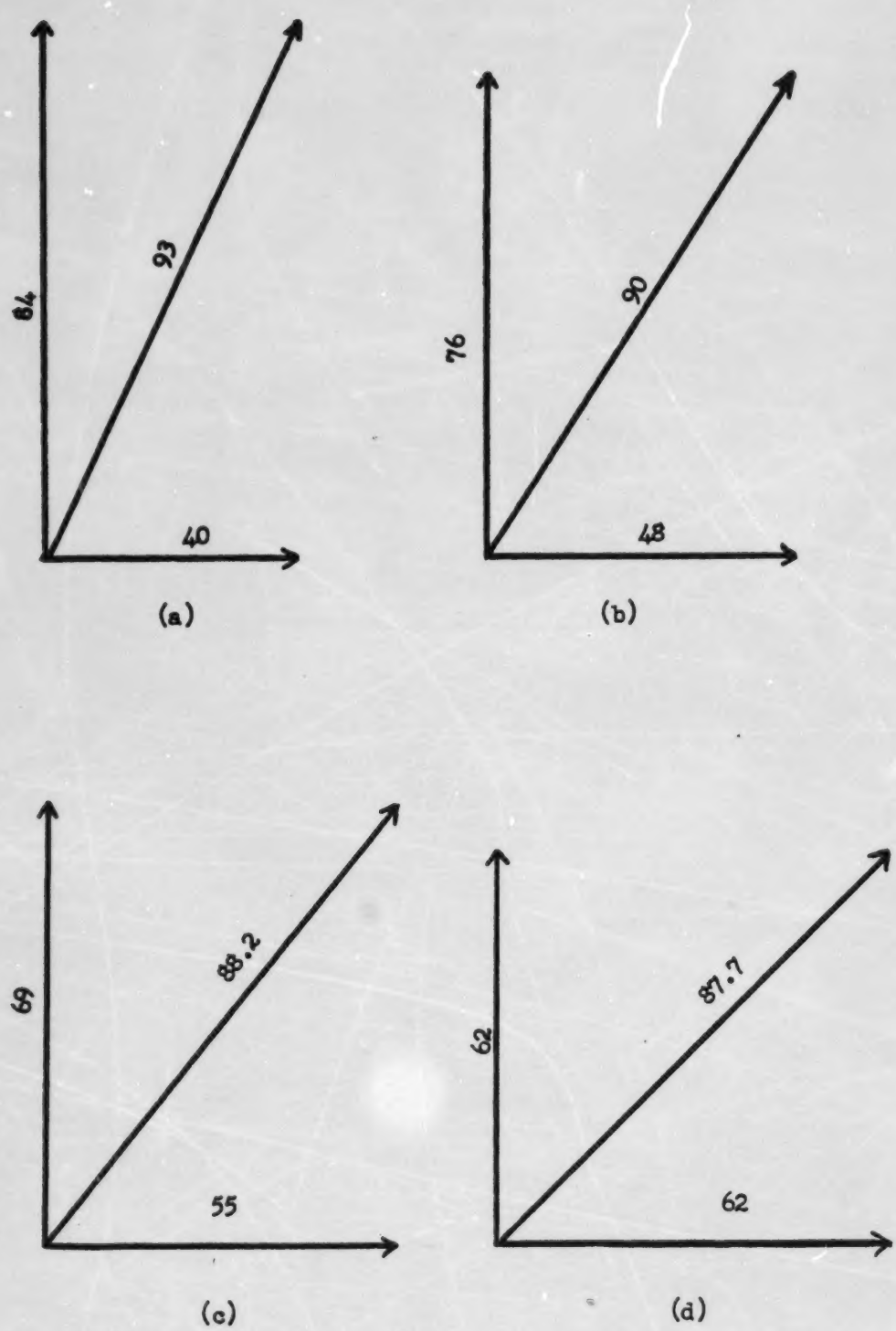


Figure 7-3. Representative G and S distributions in liberal arts curricula

magnitude as well as the directional angle for the resultant is significantly altered. As the G:S ratio becomes much smaller, it is obvious that the resultant takes on a greater S-character. Thus, the vector models draw our attention to the resultant of the interaction as well as to the component forces themselves.

A second example of the semiquantitative conclusions which can be deduced from vectorial models is derived from certain mathematical connections between the geometric vectors and the matrix elements. One can assume that the specialization and generalization vectors (s and g, respectively) have the general coordinates in three-dimensional space

$$s = (x_1, y_1, z_1); \text{ and } g = (x_2, y_2, z_2).$$

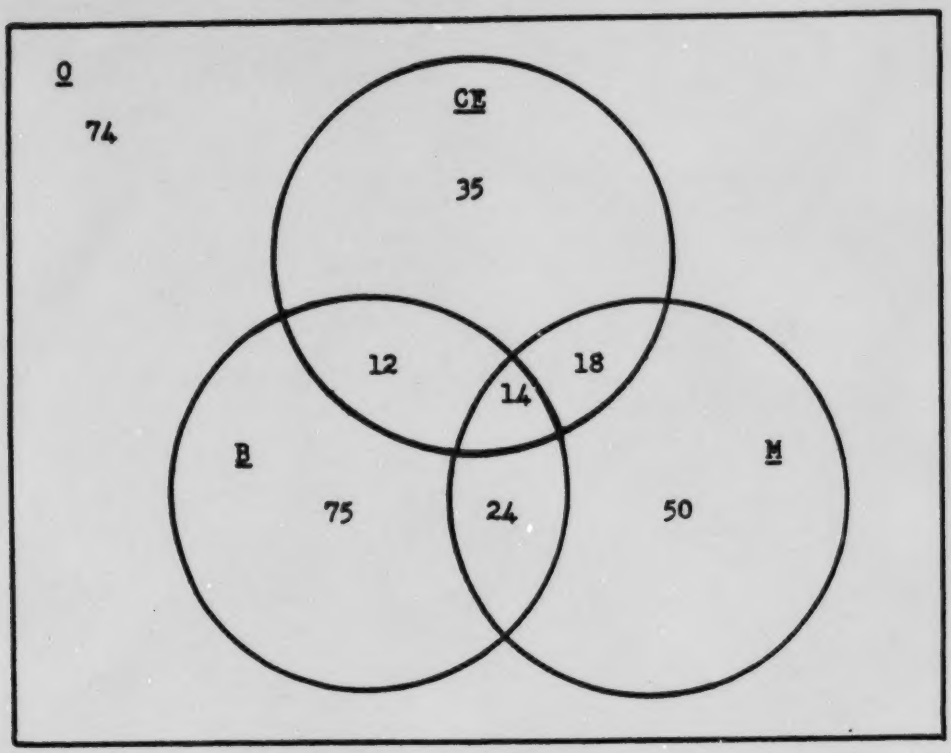
If it was decided to extend the length of the specialization vector by multiplying it by a scalar factor (c), then the effect on its coordinates would be: $cs = (cx_1, cy_1, cz_1)$. In words the coefficient c multiplies the length of s without changing the direction of the vector (s). Also, if we add the two vectors s and g, the effect upon their coordinates can be stated as: $s + g = (x_1 + x_2, y_1 + y_2, z_1 + z_2)$. The same operations can now be represented by the column matrices:

$$cs = \begin{bmatrix} cx_1 \\ cy_1 \\ cz_1 \end{bmatrix} \quad \text{and} \quad s + g = \begin{bmatrix} x_1 + x_2 \\ y_1 + y_2 \\ z_1 + z_2 \end{bmatrix}.$$

Thus, there is a clear parallelism between the properties of the geometric s vector and its column vector in the matrix. Conclusions expressed in geometric terms are also valid when stated in the matrix form, and vice versa. Therefore, a geometric interpretation of the significance of the column vector is allowed; and, for the specific case above, either increasing or decreasing the weight factor (c) for specialized studies in the curriculum changes only the magnitude of the c·s product. As a curricular force, its orientation with respect to general education remains unaltered; and with respect to the vectorial patterns in Figure 7-3 it is clear that simply increasing the specialized studies from 60 to 80 credits does not change its angular relationship to the generalization vector.

Like the probabilistic modelling techniques introduced in chapter 3, the Venn diagram can be used as both a quantitative device and visual device to represent the numerical relationships between sets of data in which the items are specified by a nominal scale. This role for the Venn diagram can be illustrated by the following example and Figure 7-4 involving the union of sets.

At a given college the need arose to evaluate the interdisciplinary impact among three of the major programs in the Division of Management Sciences. The raw data used for this purpose were the records of the registrar for the numbers of students completing B. S. degrees in that division over a three year period in the areas of business administration, consumer economics, and mathematics. Out of a total of 302 degrees granted in the division during this time, there were 74 completing other majors in the division (athletics, education, etc.). The main objective of the evaluation was to identify those students among the remaining 228 who took work in more than one of the three named disciplines; and the recorded data were placed into the following mutu-



Code: CE - Consumer Economics

M - Mathematics (excluding computing)

B - Business Administration

O - Others

Figure 7-4. A distribution of majors completing B. S. degrees in a Management Sciences Division

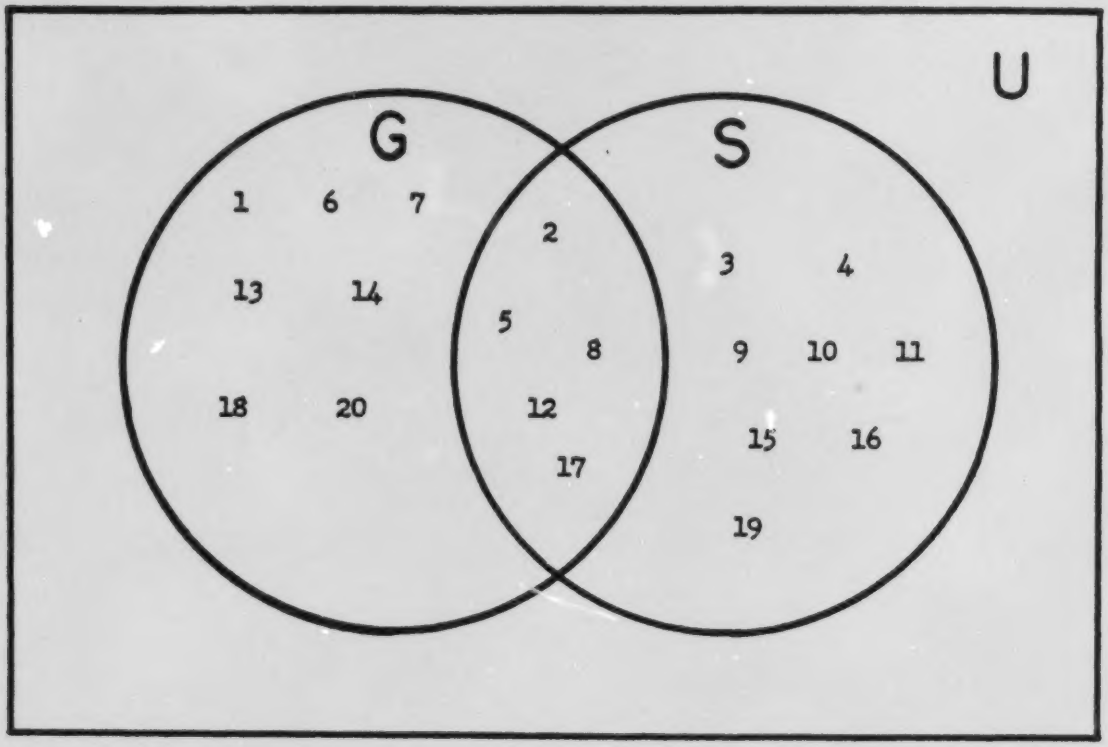
ually exclusive classes.

Business administration only	75 majors
Malthematics only (excluding computing)	50 majors
Consumer economics only	35 majors
Two or more courses in all three areas	14 majors
Business admin. major + at least 2 courses in Mathematics and Mathematics major + at least 2 courses in Business admin.	24
Business admin. major + at least 2 courses in Consumer econ. and Consumer econ. major + at least 2 courses in Business admin.	12
Consumer econ. major + at least 2 courses in Mathematics and Mathematics major + at least 2 courses in Consumer econ.	18

Since four of the above classes contain members crossing the disciplinary boundaries, the three-fold Venn diagram can be applied as shown in Figure 7-4. Among the direct conclusions to be drawn by placing the data in the diagram are the following: (a) the total number of majors in the three primary areas (business administration, mathematics, and consumer economics) account for 75% of the B. S. degrees awarded in the Division of Management Sciences; (b) out of these, 70% completed the major in the single subject area without crossing over into the other two disciplines in any substantial way (not more than a single course, and that usually being an introductory computing class); (c) a subset amounting to 6% completed their major along with substantial study in the two other cognate fields; and (d) the remaining 24% made a crossover to a single adjacent discipline. Although the same conclusions from the operations of counting and sorting the data can be deduced without using a Venn diagram, the figure visually elevates and more fully characterizes the conjunctive relationships between the various categories of numbers within that total data set. Likewise, the conclusions drawn from the diagram allow the faculty of the division to decide whether or not a change in requirements for their degree is needed in order to stimulate more interdisciplinary exchanges among the three related fields.

The Venn diagram for liberal education (Figure 1-4) provides the basis for another illustration of semiquantitative implications drawn from pictorial models. As was noted earlier, the components of the specialized and generalized dimensions of learning cannot be fully separated into the two classes even though various aspects of the curriculum may place greater emphasis upon one class or the other. Thus, we tend to identify the disciplinary major with a dominant specialization vector. The Venn diagram for this case can be extended to give a clearer statement of the nonexclusive relationships between the G and S components. In Figure 7-5 representative compilations of learning elements are classified as belonging to one of the two subsets, G and S; however, several elements must be placed in <u>both</u> subsets. It follows that the region of overlap in the Venn diagram is one of an intersection rather than a union of sets. Formal properties of that intersection can now be stated by symbols.

Let U be the universal set of all learning elements; S and G are the subsets of U; $G \cap S$ is the intersection; and $\emptyset$ is an empty set. Then, the fundamental theorems relevant to the intersection for the subsets are:



G - ELEMENTS	G ∩ S	S - ELEMENTS
1 Epistemology	2 Logical reasoning	3 Language usage
6 Model building	5 Information processing	4 Operational mathematics
7 Comparative assessments	8 Hypothesis formulation	9 Fact-data
13 Conceptualization	12 Creative synthesis	10 Manipulative skills
14 Historical perspective	17 Self-discovery	11 Taxonomic analysis
18 Values and beliefs		15 Instruments and tools
20 Dimensional experience		16 Symbolic modes
		19 Materialism

Figure 7-5. Venn diagram for the G-S intersection

1. The commutative property: $G \cap S = S \cap G$.

2. The identity properties: $S \cap U = S$

   and if $G = \emptyset$, $S \cap \emptyset = \emptyset$.

Although only a partial list of elements in each subset is included in Figure 7-5, the properties of the distribution justify several conclusions.

A. If the area of intersection describes the real interplay in liberal learning, then the commutative behavior of G and S permits us to approach that situation from either direction or either subset without altering the outcome.

B. From the identity properties, it follows that all of the elements within the intersection are lost when the elements in G are minimal as they approach the limit of an empty set. The obvious result is that liberal learning (the intersection) becomes a null set if either G or S becomes an empty set.

C. In the absence of elements in common to both G and S, the two subsets become disjoint sets, ($G \cap S = \emptyset$), and liberal learning vanishes.

D. For the condition in which G approaches an empty set, the total learning (or universal set U) becomes synomymous with the elements of specialization. Even though the above arguments may appear on the surface to be simplistic, they are fully implied by the Venn diagram used in this instance as a particular representation of liberal education.

An additional example of the more precise use of the Venn diagram can be shown in Figure 7-6 as a representation of the "learning as personal discovery" model proposed by Arthur W. Combs.[6] This particular model is derived from perceptual-humanistic psychology which emphasizes the personal discovery of meaning in learning and shares a number of ideas in common with the Lewin view of personality development. Combs has stated the basic assumption of the personal discovery theory to be that individual behavior will be influenced by information only to the extent that the individual has discovered some personal meaning within that information. The assumption follows the empirical observations in education that all experience is fundamentally subjective and both cognitive and affective learning can never be separated from value beliefs, attitudes, and feelings. Motivation then becomes an internal problem for the learner. Deductions which follow from the assumption are:

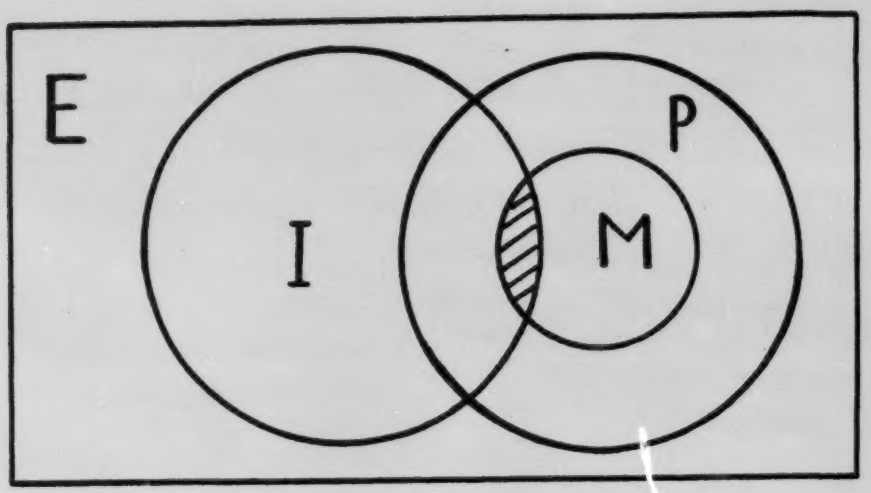
A. There must be a personal commitment by the student to the exploration of meaning.

B. The person exists within a learning environment or atmosphere composed of objects, ideas and people.

C. Within that environment are information sources including factual, technical and process elements with which the person can interact.

D. Interaction between the person and the atmosphere must be facilitated, but primarily by external manipulations.

E. The interaction of the student with new information produces learning



Code: E - Environment or Atmosphere for learning

I - Information

P - Person

M - Meaning

Figure 7-6. Venn diagram for learning as personal discovery

only when the individual senses or discovers some personal meaning from that process.

Some of the consequences of the labeled deductions above can now be analyzed with the aid of the Venn-Euler diagram in Figure 7-6.

Conditions B and C: P is a subset of E; or $P \subset E$; and $I \subset E$.

Condition C: Since the student must encounter new information or experiences, subsets P and I intersect. $I \cap P$; and $I \cap P = P \cap I$.

Condition E: The personal discovery of meaning implies that M cannot be directly manipulated externally through the atmosphere. Thus, $M \subset P$; $M \cap E = \emptyset$; and the complement of M(or M') remains in P. Since ultimately learning centers in M and information alone is without meaning, then it follows that M must interact with the intersection of I and P. In symbols this becomes $(I \cap P) \cup M$.

From the diagram, it is seen that not all of the sets of elements comprising the person-information intersection will be found to have personal meaning nor will they be incorporated into learning experiences. The teacher must assist the student in perceiving a need for undertaking the search for meaning in information as well as be concerned with the manipulation and control of the learning setting.

The important statistical analysis of empirical data concerning the impact of liberal education upon students which was made by Winter, McClelland and Stewart uses essentially the same fundamental assumptions about learning processes as does the "learning as personal discrvery" model of Combs.[7] One of their most significant test areas for the influences of liberal education on students was focused on critical thinking and analytical skills as measures of personal meaning for information. Although their results indicate that basic concept production is not altered by the environment of liberal learning, the skills in thematic and argument analysis as aspects of critical thinking and meaning are enhanced to a measurable degree. Such skills are extended by students as they encounter diverse choices and interact with novel stimuli from the learning and social environments of the college. Adaptive and integrative behavior increase somewhat from disciplined critical thinking and more personalized thought and action.[7]

The results of the quantitative study by Winter, McClelland and Stewart were deduced from a set of three test instruments adminstered to students and graduates; and these instruments were designated by the titles: test of thematic analysis; analysis of argument test; and thematic apperception test. Additional data were collected about educational outcomes for graduates in relation to career satisfactions and successes, personal feelings and the self-image, and family and voluntary associations. The several test variables concerned with learning competence and the social-personal outlook covered both the cognitive and affective domains listed below.

Cognitive	Affective
Broad analytical skills	Self-assurance and self-control
Critical thinking	Empathetic understanding
Methods of learning	Maturity of emotional judgements
Independent thinking	Values in the social dimension

Standard techniques for identifying statistical correlations were used; and in the affective domain the evidence seems to indicate a positive effect of liberal education upon all of those characteristics listed above. On the other hand, there is no apparent change in two of the cognitive variables, methods for learning and some aspects of independent thinking, which can be traced to liberal education at the particular colleges included in the study. Nevertheless, the investigation by Winter, McClelland and Stewart fully demonstrates that standard quantitative research methods used in the social sciences can be applied with some success to educational constructs like the "learning as personal discovery" model as one view of student learning behavior.

Other approaches to quantitative and numerical extensions of the models for liberal learning include the applications of systems of linear equations noted briefly in describing submatrix representations for generalization vectors in chapter 3; and similarly, linear functions were used to define the decision boundaries in pattern recognition procedures. The latter are expanded conceptually in the discussion of the binary classifier in Appendix 2. A related example of simulation techniques using linear equations is the multiparameter model for student retention developed by Norman Aitken.[8] In this case the measure of retention (R) is given by the summation of five primary variables: academic satisfaction (A_s; living satisfaction (L_s); academic performance (A_p); extracurricular activities (E_i); and external factors (E_x), including financial and family influences.

$$R = a_o + a_1A_s + a_2L_s + a_3A_p + a_4E_i + a_5E_x + u_R$$

The coefficients (a_1, a_2 ... etc.) as well as the intercept a_o and the random error term (u_R) are evaluated empirically. It is Aitken's conclusion that the first three variables are the dominant ones in the model and he further analyzes these by resolving each one into sets of more specific factors influencing the composite variables A_s, A_p and L_s. Such a structural model rationally assumes that factors directly shaping the quality of students college experiences will have a causal relationship to their decisions to remain for another year with a given institution and its educational programs.

Whether one chooses to rely upon a more quantitative model or finds a simple descriptive diagram to be sufficient, the investment of the necessary effort into the formulation of curricular models should make the educator more aware of the variance in educational processes included in that often abused label, liberal education. The representation of the curriculum or learning problem in mathematically derived terms requires some identifiable correspondence between the real-world process and a mathematical structure. However, theoretical treatments of curricular structures must not be restricted to exclusively mathematical formulations for, as Beauchamp has stressed, complete curricular plans include the institutional goals, learning objectives, subject content, and strategies for instruction, as well as the assembled overall designs and the schemes for their evaluation.[9] The planning and implement-

al functions for the curricula will be less adapted to numerical descriptions than the decisional and evaluative needs stated as data representing educational outcomes. Nevertheless, it has been demonstrated that semiquantitative models of curricula can be constructed in which the initial axiomatic propositions about learning processes and the interactive roles of directional elements shaping those processes are represented more precisely. Four fundamental parts of an optimal curriculum model as an organizational structure will be its starting conceptual definitions, its explanations of the processes to be depicted, its predictions, and the methods to be used for its evaluation. It is the latter pair of characteristics which are amenable to quantitative or empirical specification and which tie our analytical-theoretical models to the real world of educational practice.

The mathematically based model provides us with a greater degree of organizational control over the learning system through its requirements of critical statements of essential terms as well as its elevated emphases given to inferences to be drawn and the possible relationships to be expected. In those models incorporating quantitative information about the educational outcomes it is the numerical relationships which provide the most direct tests for the adequacy of the predictions deduced from a given model.

Educational problems often differ from those in the sciences by involving many more interdependent variables. An important consequence of this difference is that models of educational systems (i.e. the curriculum) may appear as initially crude approximations of the real learning system; however, even by using such approximations the model may yield useful general predictions which would not arise from verbal analysis alone. In the absence of predicted numerical outcomes, a mathematically-based model can still help us think through the mental tangles of our own verbal arguments toward more precise statements about the problem and toward the identification of the most significant variables influencing the solutions to that problem. By reducing the number of variables to a minimal set of descriptors of learning, we may then be able to strengthen our representation of the system by visually and symbolically reducing the seeming randomness in that educational system as well. As we increase the precision of our language, both the assumptions we make about learning and the limitations implied by those assumptions become clearer. The fact that alternative curricular structures can be represented by contrasting models should help us select or construct rational programs which will more closely match the stated educational objectives of the college at a given time and should facilitate the operation of that learning system as it relates to student development in a liberal arts setting.

Chapter VIII

INSTITUTIONAL GOALS AND THE CURRICULUM

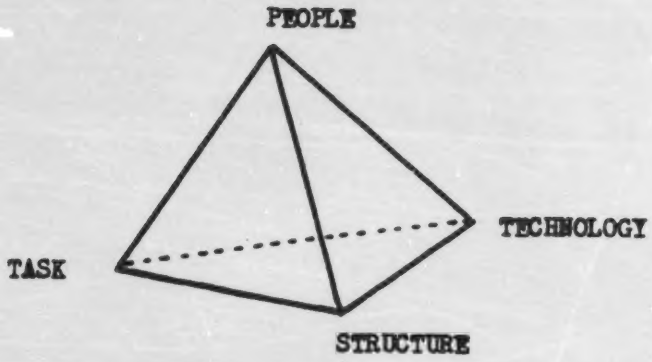
As was observed early in this essay, the macroscale structure of institutional goals must be considered separately from the educational micro-objectives which center on the individual learner; however, the broad outline of the curriculum certainly bears the impact of both levels of objectives. A detailed examination of goal formulation is beyond the scope of this study. Nevertheless critical areas touching on curriculum planning should be noted. There have been numerous reviews of appropriate models for the overall management of institutional programs for higher education; and goal setting and the accompanying organizational consequences for program development have been thoroughly examined elsewhere.[1]

Establishing Institutional and Curricular Objectives

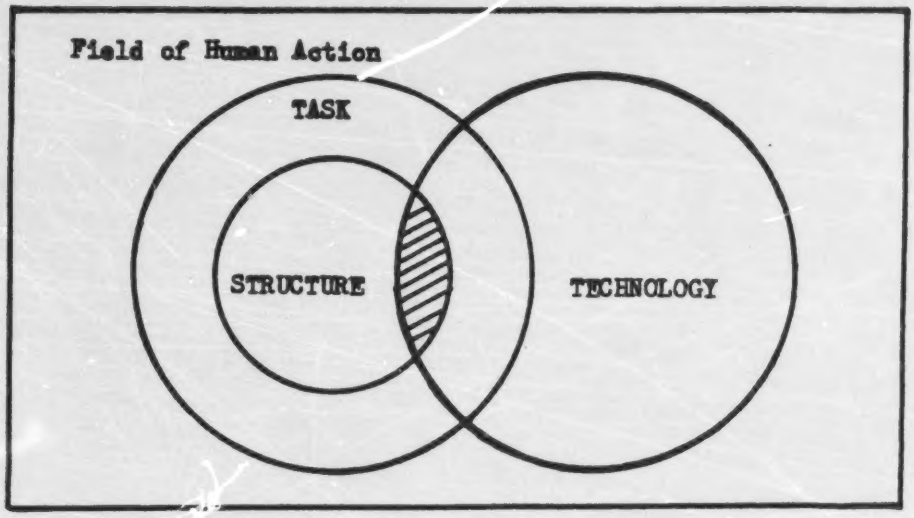
At the strategic level of curriculum planning, it is obvious that the development of a set of workable analytical models is but one step in a total process terminating in the adoption and implementation of a complete program for liberal education. To place functionally that curriculum development task within the context of the overall setting of institutional goals, it is helpful to draw upon descriptions of organizational behavior used in the field of management. One of the simplest and yet quite useful approaches to depicting organizational behavior is the Leavitt model; and its implications for higher educational administration have been reviewed by H. R. Bobbitt and O. C. Behling.[2] In this management perspective the orientation is largely an empirical and non-normative one in which both the individual and the small group act within an environment of the total organization while attempting to develop tools and procedures for obtaining the desired outcomes for the institution.

The Leavitt model of organization identifies four primary interacting determinants which will in effect federalize the goal outcomes, namely the persons, the task, structure, and technology. In this instance the task is the formulation of a set of educational goals, whereas the technology will include any procedures, models or tools which are beneficial in problem solving. Leavitt uses the term, structure, in the sense of the organization of the social group itself as it assumes the responsibility for the problem and for obtaining a solution to it. The structure of the group may be the corporate mode at one extreme in which a single individual is the central authority managing the functions of the group and formulating its output. Or, at the opposite end of a continuum the structure may reflect a voluntary alignment of peers with the expectation that a solution to the problem will be reached by consensus. The original visual model of Leavitt was a simple diamond-shape with each of the determinants located at the four corners of a square. For our purposes, the interconnections between the elemental components of the model can be extended by the diagrams in Figure 8-1.

By elevating the Leavitt organizational model initially to a three-dimensional form, the range of interactions between all of the paired elements is still retained. In the tetrahedral form in Figure 8-1A the edges show that each element interacts with the remaining three components. For example, persons interrelate with the task, the technology, and the structure, whereas



A. Interacting elements in an organizational system



B. Venn diagram for interacting elements

Figure 8-1. Variations on the Leavitt model for interconnected elements in an educational organization

the technology must be interactive with the task, the structure, and the persons. Beyond these edge relationships, the faces of the tetrahedron illustrate common fields of interaction through three-component associations as well. The people-task-technology plane defines a subordinate area of interaction which may operate as a separate unit in goal formulation. Or, in the early stages of work on a goal problem, the people-structure-technology surface may be isolated in order to set the operational framework in place for further study and action by the group. Thus, the effectiveness of the total organization in dealing with the overall problem of goal indentification may be determined as much by subset interactions shown by the triangular faces as by those connections identified through the edges in the figure.

Other implications found in the Leavitt model are shown by Figure 8-1B. If the development or revision of the educational goals is centered more upon the personal growth of the participants than upon the macro-scale institutional development, then the Venn diagram is again helpful in visualizing the interdependency of the component parts. In this instance the composite problem solution system is a subordinate part and created from the intellectual activity of the persons in the group; and yet both the task and the technology are strongly interacting elements in the field of human actions concerned with goals for learning. However, at this level the dimensional element of structure need not be viewed as a pattern of social group relationships, but rather as an armature for supporting the task of goal development. In this sense the structure is an organizational lattice which, like the task itself, must interact with the appropriate technology by sharing common factors with it. At the same time, the task-technology interaction cannot yield identical influences since each element has its own unique properties, and the goal statements cannot be specified exclusively from any one of its single sources.

In the recent past we have tended to be satisfied with a single focal point in our goals for liberal learning with little attention being given to the comprehensive endeavor posed by the curriculum as a whole. Thus, in the more traditional approaches much time and effort has been expended upon content and skills components within a set of requirements however refined our labels may be ("intellectual experiences", "body of knowledge", etc.). Most would agree that the intent of a given curriculum is an important facet of any set of statements about goals for undergraduate education. Likewise, the outcomes and evidences for learning must serve as the empirical checks upon those intentions, regardless of the adopted set of stipulated contents for the liberal arts curriculum. For most of the liberal arts colleges, the institutional goals will need to address more than the task-technology intersection and the content elements of the derived educational program.

In discussing goals, purposes, and objectives in education Paul Dressel has appropriately restricted the use of the term, objectives, to a more limited set of statements about expectations for particular programs developed within a given institution of higher education.[3] Such objectives differ from institutional goals in being essentially educational in their intent and are central to the individual student as a person rather than being theoretical statements about learning and teaching processes. Dressel has proposed four objectives for personal growth during any college program: (a) the humanizing dimension as an essential component of liberal education; (b) the socializing aspect; (c) individualization as a dimension for growth in terms of abilities, skills, and personal values; and (d) a developed sense of community in both

the political and disciplinary realms.[3] The structural areas at which these program objectives are likely to be applied can range from the disciplines to interdisciplinary curricula in which mental, intellectual and personal development become paramount factors in higher education. Many examples of specific curricula representing different types of objectives have been reviewed in the study prepared for the Council for the Advancement of Small Colleges[4], and the reader should consult that excellent resource for more information.

The "strategic market planning system" proposed by Philip Kotler and Patrick Murphy[5] broadly extends the Leavitt organizational model to the total educational structures of colleges and universities. As an economic model, the system is centered on planning functions and operations oriented toward program marketing and directed toward identified consumers (students) with changing interests and needs. The overall format of the Kotler-Murphy strategic planning system is outlined in Figure 8-2, and at the fundamental level the intent of the system is that there will be a matching of the educational organization with its identified but changing market of incoming and leaving students.

The initial task for this planning system is an environmental analysis in the sense of identifying those internal and external factors influencing market trends. Beyond the usual inputs from institutional personnel, other factors related to the cultural, economic, employer, and professional school expectations and pressures must be confronted. Likewise, negative factors from competitive institutions, demographic trends and public attitudes are included in the environmental analysis as threats. An analysis of resources will include not only an audit of financial and physical resources, but also special institutional strengths in programs, facilities, personnel, and sources for student recruitment.

Following the analytical stage, a mission statement for the institution must be developed in which the overall purposes of the college are made clear and relevant. The concise descriptors used by Kotler and Murphy for an effective mission statement set the correct tone for its development, namely, it ought to be feasible, specific, and motivating, as well market-oriented.[5] On the other hand, the objectives derived from that mission statement are limited in scope as was emphasized in Dressel's set of goals.

As an operational step, the strategy formulation stage in Figure 8-2 encompasses decisions about retention of some parts of an existing program along with the additions and expansions of the program as deduced from the mission statement and the resource-environmental analysis. The approach utilized by Kotler and Murphy in this area is expected to counteract the seemingly random expansion and initiation of programs in the colleges during past decades when funds and students were plentiful. The strategy formulation step is envisioned as a much more rational planning operation within the restraints of the adopted goal structures. An essential outgrowth of strategy formulation is that new or modified organizational schemes within the institutional resources and personnel may be needed to fully implement the adopted strategic plan. As an economic model, the success of the total plan will depend upon the final marketing step and the monitoring of its effectiveness. The rapidity with which the institution can respond to changing conditions will determine the effectiveness of the system, as well.

Even though purely economic language and planning designs may have lit-

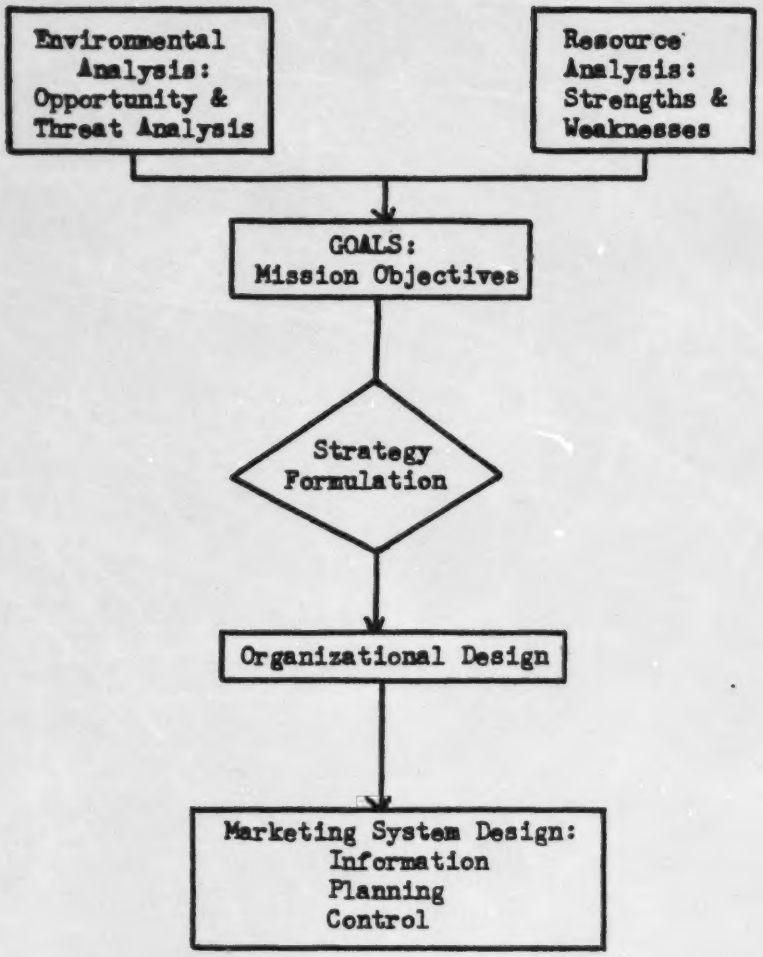


Figure 8-2. An economic model based on strategic planning

tle appeal to many of the faculty in liberal arts colleges, the insistence of marketing advocates upon a thorough analysis of resources and goals as a preliminary step to curriculum re-organization cannot be faulted. Similarly, our procedures for systematizing those processes for program appraisal and modification need to be concerned with both the possible and the probable futures for the educational institution as an intentional organization fostering learning. Other proposals sharing those concurrent and yet projective functions in planning need to be examined.

For higher education, it would appear that goal statements have two general and distinctive functions: (a) definitive roles which state the characteristics of the institution, its various clienteles, its priorities, and its expected educational outcomes; and (b) an idealized standard against which the real performance of the institution, its subunits, and its members can be compared and evaluated. Beyond the explicit stated goals may be overriding implicit values determined by the individuals making the day-to-day decisions and imprinted by the national or regional cultural values and expectations. Clifton Conrad has adapted the term, constraint, to describe such a combination of factors influencing the direction of the decision-making processes.[6] Thus, the constraints upon the goals of liberal arts institutions must include the value biases which the students, faculty, administrators and governing board members bring with them when they join the organization. From the interactions of these persons within the institution and with the various publics related to it, operational goals as well as definitive goal statements take shape.

The overall pattern of the curriculum is strongly influenced by both institutional beliefs and the mission-mode complex as perceived by the faculty. It is the latter determinant which is the larger force shaping the curriculum and specific requirements then extracted from the disciplines. Counterforces to the disciplinary-faculty influences are often limited to the pragmatic elements of financial restrictions, student enrollments and competing educational institutions. If valid institutional beliefs are to be made explicit as well as operational, then two proposals made by Conrad can be tried, namely, (a) identifying and evaluating the constraints by rank,[6] and (b) identifying the means and priorities for activating those beliefs.

Initial operations required to identify and re-define the educational priorities and goals for the institution can be placed within the total sequence for curriculum development as illustrated by the flowchart in Figure 8-3. Here, the first organization problem is to establish the broad framework for action including the three interacting elements of people, task and structure. Although there are various ways for selecting the work group to be assigned the task, the usual practice is to appoint a new select committee to work with the single problem of the curriculum revision as a comprehensive task. The same core group of people will coordinate the total problem from its initiation through final acceptance and implementation. As designated in the flowchart, the first activities of the task force must be centered upon a modest assessment of the existing program in order to examine both its strengths and weaknesses as well as its impact upon recent and current students. Clearly, if the institution is committing itself to setting new directions in program or is appealing to a different population of prospective students, such factors will give impetus for the development of new goals and a greatly altered program.

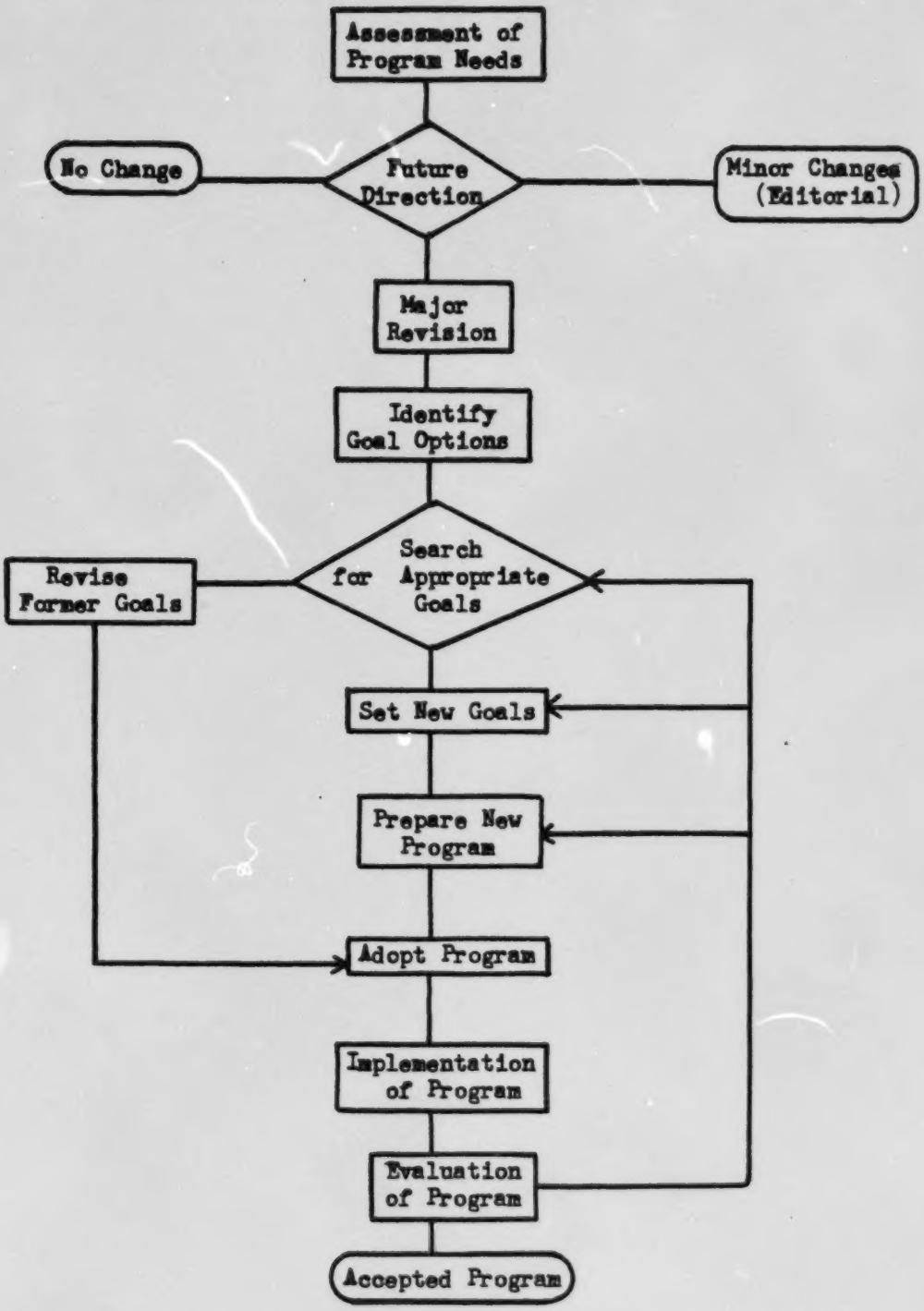


Figure 8-3. Overview of task and structural elements in program development

On the other hand, if the task force concludes that the existing major educational objectives are sound, identifiable weaknesses in educational practice may be remedied by minor shifts in requirements or revisions of the content of specific aspects of a current program. However, the task force must be prepared to adequately defend its first decision concerning the future direction for its work before proceeding with further steps. After that initial decision has been confirmed, the task is now firmly defined and the remaining organizational efforts must focus upon structural and technological aspects of the problem-solution system.

As the group concentrates on the means for solving the program development problem, it must keep the set of intended goals for the new program in constant view as a reference standard for checking their various program options. In the usual case a broad range of possible program directions has been identified in both the early stage of assessment of needs and in the search for appropriate goals. As these operations proceed toward establishing new goals, it may be possible to subdivide the potential goals into classes: essential and desirable; or a further option is to rank the goals in an order of their educational importance to the group.

Our college catalogs usually have an early brief section on institutional goals and a fuller treatment of the topic is always a part of any institutional self-study. Whether such statements are definitive or idealized standards, their forms commonly reflect a normative view as an educational philosophy. Elements of the statement may include value commitments, definitions of liberal education or teaching modes, anticipated educational outcomes, and metaphysical hypotheses. Thus, the summary in a catalog gives one set of premises upon which the institution claims to operate; and the reader of these goals is expected to conclude that there is a plausible matching of the curriculum and learning modes with those principles.

After clarifying institutional objectives, the appropriate methods for directing the instructional process toward those goals will evolve within the educational and environmental mix of faculty and students. However, if the disciplines and their factual contents remain the primary center for the process, the means will be chosen for the most effective conveyors of information. If a less restrictive objective is to be pursued, then other types of education as classified by Joyce and Weil should be examined.[7] In that scheme the fundamental or basic education involving linguistic and manipulative skills and an information core represents one facet of education as a whole learning experience. Other alternative centroids are: (a) the disciplinary inquiry involving concept discovery and field methodology; (b) personal development with an emphasis upon the extension of creativity and self-discovery; and (c) dialogue in which the social dimension undergoes alteration and growth through interpersonal learning exchanges in groups. Therefore, a pluralism of educational missions dictates a diversity in educational modes and the model for each must clearly label the distinctive features in each type of learning situation. Such a model may be simply descriptive as an overview of the process and its emphasis; or alternately, the model may serve the purpose of a design for structuring and implementing a particular learning system along with its smaller instructional units. Also, the model will demonstrate the varying degrees to which the form of the curriculum mirrors a range of strategies for learning.

If the decision has been made that a comprehensive change in the college curriculum is necessary, then a more detailed view for the placement of the goal formulation and implementation steps can be represented by a flowchart like that shown in Figure 8-4. In this diagram special attention is given to sources of input entries as the determinants of the goals for the educational program as well as to the place of subgoals in relation to the general studies portion of that program. Although the social-environmental mix conditions all of the elements shaping the objectives, only the major groups of persons directly supplying inputs into the formulative stage are listed as entries for the overall process. The particular data-item inputs can be derived from tabulated reductions of information from questionnaires, the Delphi method, and informal group discussions. However, the decision stage of the search step must include the realities of the entering behavior and expectations of the present and future student group if workable normative objectives are to evolve. The educational objectives shown on Figure 8-4 have been subdivided in accord with the suggestions of Saylor and Alexander[8] who have observed that the objectives are multileveled and will include: (a) broad and often abstract statements of educational philosophy as well as assumed value commitments, and all stated as general goals; and (b) subgoals as subordinate but explicit objectives for student behavior stated in terms of skills, experiences, and awareness. It is the subgoals which are tied directly to the development of particular instructional strategies. For the cognitive dimensions of learning, the subgoals can be related to student performance through behavioral objectives and programmed instruction. Thus, the subgoals are specific and detailed operational statements rather than the more broadly stated major goals as overall directives for the educational process. If the intersection for liberal learning is determined by the intermingling of general and specialized studies, then the various subgoals leading to that synthesis will shape the content and scope of both realms of study, and these in turn provide the inputs for the design of the total curriculum.

The subgoals are usually easier to transform into specific learning objectives and activities since it is these which are the most familiar components to teaching faculty and also are among the least controversial. For example, particular skills in communication are accepted as the most fundamental competencies expected for all college students and clearly transcend all other curricular requirements. Similarly, subgoals concerned with the clarification of values and attitudes will shape the academic progress of students in both general and specialized studies. Once the subgoals are identified, their translation into curricular components can follow directly; however, since each subgoal can in principle be universalized with respect to the curriculum as a whole, the most suitable and effective methods for teaching must be selected in order to avoid the risk of each subgoal becoming encased in an isolated required course or in separated units of learning exercises.

The evaluation step in Figure 8-4 gives emphasis to an important and integral part of the total planning sequence for the goals and the curriculum. A number of sources for evaluating the outcomes should be included in addition to those related to the students (i.e. test instruments measuring knowledge, abilities, attitudes). Among these sources are: (a) ratings on the extent of implementation of specific subgoals and derived activities; (b) assessment and evaluation of instructional systems and materials; and (c) the faculty appraisal of the effectiveness of both the elemental content of the curriculum and its compatibility with the subgoals of the institution.[8] In

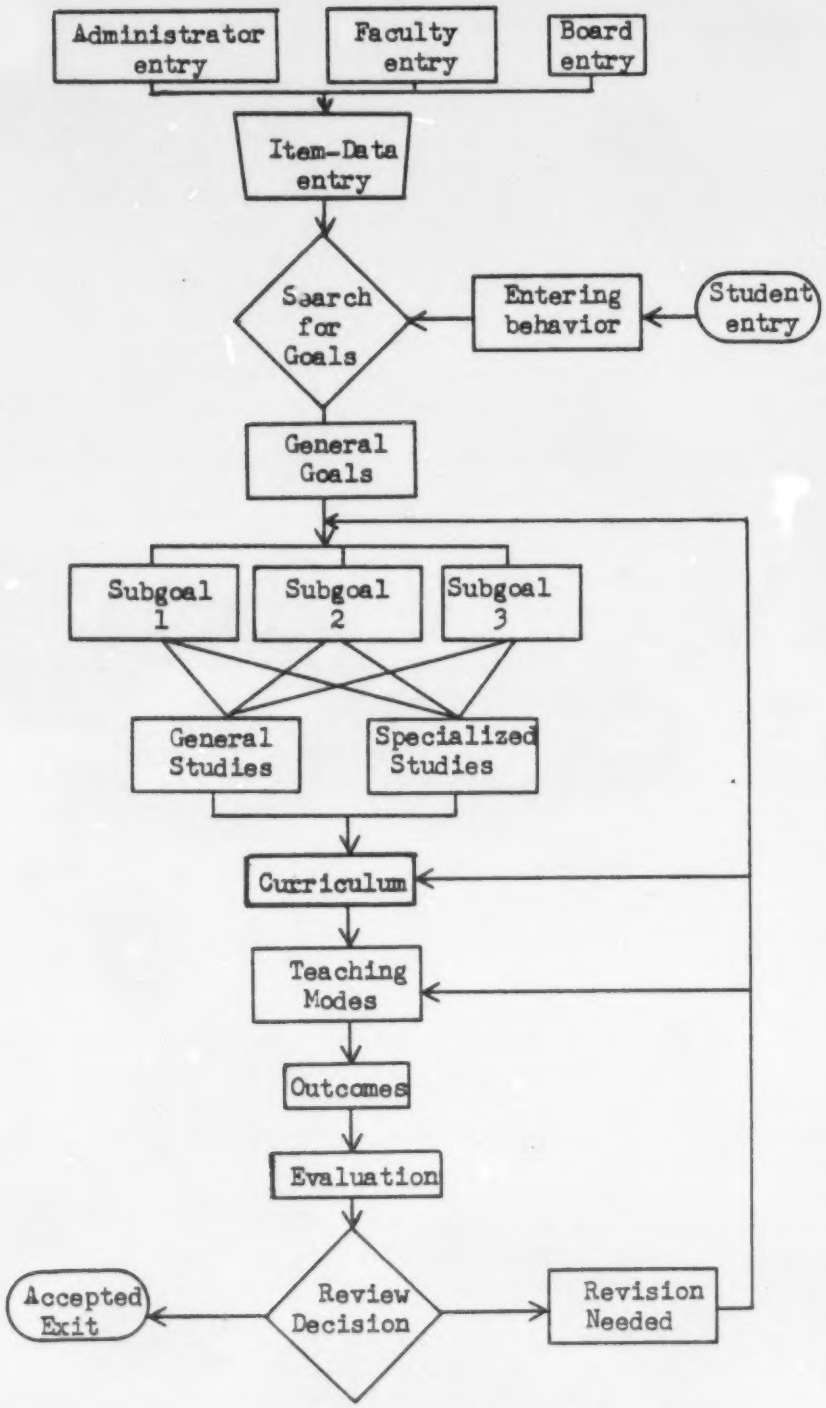


Figure 8-4. Objectives related to the liberal arts curriculum

Figure 8-4 the review-decision step following the evaluation allows a possible feedback option to critical stages for the revision of the curriculum, teaching modes, or even the subgoals already in use.

To some extent, evaluation is a part of the early stages of program revision as well as in the formalized later step in the total development process. However, at the formative stage the uses of evaluation are centered on identification of weaknesses and the correction of errors as the subgoals evolve. Such evaluative operations are always referenced toward an expected result, and, therefore, are normative comparisons intended to aid in strengthening the specified subgoals before their implementation.

One important aspect of the evaluation process is to select some indicators as responses to outcomes of the program which will show that the intentions of the objectives and subgoals have been fulfilled. These indicators need not be restricted to test formats, but might include observations concerning the processes of learning used by students in the program and surveys of products or performances by the students in different areas of the curriculum. The more classical sequence in educational testing, i.e. pre-test -- learning actions -- post-test, is rarely applicable to the evaluation step in collegiate program development as depicted in Figure 8-4. Before and after surveys or interviews may come as close to that idealized form as is possible in so large a multiple variable problem as the revision of a total program for liberal learning. Nevertheless, some effort must be made to collect usable and somewhat objective information which will reflect the extent to which the content of the new program has been effective in meeting the specified objectives. The outcomes from the evaluations then provide the basis for more reliable remedial changes before the final adoption of the program is to be recommended by the task force. The evaluation stage is not an end in itself but a plateau for developmental hesitation, and after that pause in the planning process, the task group must decide if revisionary feedback cycles are needed. Thus, the evaluation requires gathering, combining and interpreting the relevant information about the operation of the new program in order that reasonable and significant educational decisions can be made.

Some Conclusions

Any curriculum is the product of intentional activity and has a prefatory set of specific ends of one type or another. The development of that product begins with an assessment of the institutional goals and needs and is followed by the selection of a format, content, and methodology for learning meshing with those goals. As has been noted by Earl Clark, the articulated objectives or ends-in-view should be the terminal elements in common to both teaching and learning; and the instructional actions along with the content of the curriculum must be related directly to those goals.[9] A final evaluation step must go beyond means toward a functional analysis of both institutional attainment and student performance, and this outcome then becomes the initiator for further revision of the curriculum.

Curriculum development as a more comprehensive undertaking requires by implication some cohesive view of the potential of individuals for growth and the selection or design of a progressive system for the enhancement of these designated human qualities through learning. Meaningful knowledge generated within and beyond the formal learning environment of the college

should possess a degree of unity and relatedness to the person which will equip that person to live constructively within a social structure and to be a responsible participant in the processes of the community. Choices must be made by that person acting and reacting within the context of real adult living. The earth and all of its living forms has been subjected to unparalleled tensions and accelerated ecological changes during this century, and in spite of our very sophisticated technology we must often confront the unexpected and indeed those unwelcome events which disrupt personal and career development. However, experience strongly suggests that persons frequently tend to construct responses to the new based on too few alternatives and to make important decisions from trivial or undifferentiated inputs. Although probable consequences are difficult to assess, life circumstances are usually complex and require a more complete analysis of the range of non-obvious possibilities. Ideally, liberal arts experiences should prepare individuals to more actively shape the development of their own life-long patterns of mental activities, skills, and problem-solution strategies in an environment of discomforting personal stresses and turbulent social-economic conditions. Yet curricular designs must always be viewed as tentative since our fundamental and assumed information base concerning the mental growth and learning processes is continually being revised; and the curriculum, teaching and learning must remain interrelated through the sharing of common variables originating with the person in a learning field.

It was observed early in this essay that liberal learning is usually characterized by a diversity of educational experiences and ideas drawn from many academic disciplines. However, this common diversity must exist within a setting of a common unity for both the goals and the fundamental learning processes being cultivated by the student during the undergraduate years. Therefore, liberal learning requires modes of action and changes of behavior in which there is some evidence of continuity and direction within that total process. The emergent patterns must be substantive as well as directive with larger goals than the mastery of specific disciplines and the enhancement of particular skills.

As we initiate revisions of undergraduate curricula, there is a current tendency upon the part of faculty to advocate change as a response to vaguely sensed dissatisfactions with an existing program; and often these are based upon superficial and largely subjective assessments of student experiences as stated by vocal faculty critics teaching within that program. Similarly, the temptation to accept as our only option a nostalgic return to the general requirements of our own undergraduate time is all too strong. Yet no amount of expensive teaching gadgetry nor unusual instructional techniques can obscure the real image of any program of liberal education which seems to ignore the past thirty-five years of human development as well as the pre-college educational experiences and environments of our students. All areas of modern intellectual activities have become global and international in their contexts; and yet both the linking and conflicting ideas about the current setting force us to more actively re-examine past assumptions about the goals for liberal education. At the very least we need to hear other voices than our own, for we repeat the all-too-familiar provincial arguments about the relative significance of particular disciplines as requirements. Appropriate central concerns in any system for contemporary liberal education should be the enhancement of learning as a process and the changing of attitudes and perspectives toward the whole social-physical environment as well as toward

the disciplinary major and future occupational work of the student.

Certainly, educational and curricular planning must begin with an adequate factual basis for goal development, and that information base must be verifiable as well as accurate. Although the logical-empirical skills which we normally associate with modern planning and management procedures are fundamental to any rational effort in program revision, these tools by themselves cannot assure a successful outcome. At its very foundation liberal learning is a concept having certain identifiable features which allow us to distinguish between differing example programs in terms of the existence or absence of key characteristics which we associate with that concept. As a concept label sharing both special characteristics and anticipated consequences, liberal education must be changed and updated to provide a generalized intellectual framework which is sufficiently inclusive of process and content elements for meaningful learning to occur. In liberal learning our facts, skills, and objectives are placed within intermingled regions in a learning field which is shaped in the end by the attitudes of both the planners and the students. Actions are anticipated from students as outgrowths of such meaningful learning, and the desired consequences are very real even though our broad conceptual image of liberal education is stated abstractly.

Developmental problems in higher education arise in all areas: organization, curricula, instruction, as well as in the formulation of goals. Some of these educational problems raise philosophical issues, but others are primarily methodological and technical in perspective. However, in all instances it is essential that reasoned proposals be formulated so that clarifying language and symbols can reduce the vagueness and ambiguity in our planning documents while attending to our philosophical arguments for a cohesive program of liberal education. In all of our definitions, including liberal learning itself, we are selective in our specifications; and rather than identifying liberal education with a particular epistemological viewpoint a stronger case can be made for focusing on those characteristic learning processes, behaviors and attitudes which we seek to enhance during the undergraduate educational experience. In any learning environment it is evident that the person responds, reasons, acts and may react with emotion; and, thus, a curriculum centered on content alone is likely to be inadequate in stimulating and integrating imagination, commitment, or expansive thought with the student's real world of both personal and social action. Indeed, all would agree that the disciplines themselves are growing, changing and dynamic systems of knowledge with which the individuals and groups interact; and yet within a given subject field the individual student personalizes the meaning of knowledge through processes of modification of information, reflective thought and conceptualization. Like a required minimal familiarity with language and common symbolic representational systems, critical thinking is but one cognitive dimension of liberal learning.

The metaproblem for curriculum development in undergraduate institutions remains one of alteration of our traditional methodology at all levels of planning, including the formulation of our goals and subgoals in liberal education. If the general goals logically necessitate a greater individualizing of the instructional system, a number of content and mode variables must be re-examined. Walter and Funk have suggested that these variables arise from two distinct but interacting classes: (a) instructional components (teaching objectives, diagnosis, instruction and evaluation); and (b) operational roles

for the teacher and students as prescriptors of the elements of instruction.[10]

The input instructional components remain the same -- print and electronic media as well as verbal sources; however, if the operational roles are to be nearly completely student-controlled, then pre-requisite learning skills must be well developed. Even in highly individualized instructional systems the usual variables related to the learner still exist, i.e. intellectual, attitudinal, personality, aptitudinal, as well as ideological. The instructor's role in the more traditional curricular forms may be at one extreme narrowly confined in relation to a particular subject field or at the other as one engaged in a transcendental exchange with the student.

For those instructional programs having goals stressing cognitive growth, a number of dimensional objectives can be included in an information processing model for learning in the general as well as specialized areas of the program. Beyond the specific ways and means for handling knowledge inputs, meaning or comprehension is a paramount consideration to the learner and this characteristic will be reflected by the ability of the student to explain, paraphrase, or interpret information. Closely related to knowledge comprehension is the task of analysis of information by validation and by discriminating or distinguishing categories within the information set and to form hypotheses. This organizational transformation of information may well be a highly personalized or subjective operation for integrating the information for meaning and long-term storage in memory. Problem-solving and synthesizing knowledge into new and creative combinations also are essential parts of cognitive development by the individual, and particularly so within general studies curricula dominated by the disciplines. Likewise, if the outcomes of learning take some linguistic or expressive form of artistic performance, the observed behavioral-attitudinal changes are dependent variables as evidences of student learning. Development of the affective domain is similarly dependent upon intellectual growth as well as on abstract and reflective reasoning. Both inductive and deductive processes are necessary in cognitive learning fostering complex problem-solving activity as an educational objective in general and specialized studies.

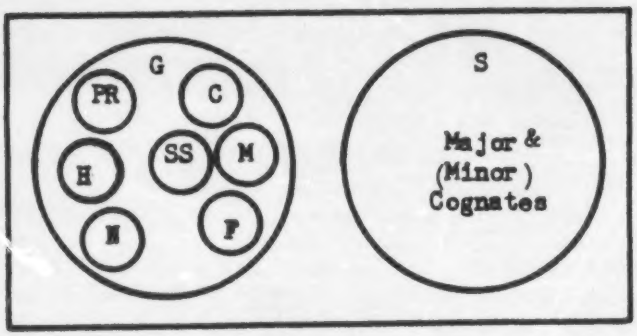
For whatever alternative goals and priorities for liberal learning a college faculty may select, a broad range of potential modelling techniques are available to assist the group in planning the specifically derived program and the curriculum. There should be no expectation that identical curricula must be the outcome anymore than that uniform objectives must apply to all liberal arts colleges. The term, purposive system, can be used to describe this condition in which the final outcomes of the teaching-learning intersection are achieved by different paths though sharing a number of general and common goals.[11] Such a process-oriented system allows choices for both contents and modes of learning while encouraging responsive rather than reactive behavior on the part of students pursuing those particular goals. The model for the system provides the planner with a visualization of the necessary conceptual framework expressing both the functional connections between variables and the underlying foundation for an integrated educational scheme. However, ultimately liberal education is a learning system delimited by the meanings of knowledge patterns within and across disciplinary zones, and the curriculum model maps the contours within that transforming domain.

As one examines the processes and evidences for learning in the college setting, it appears that many features and qualities which we associate with

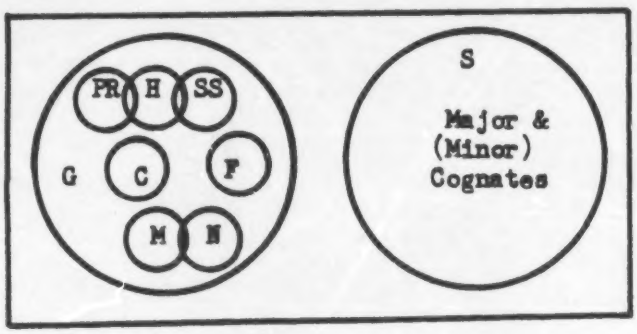
liberal education cannot be reduced to unambiguous verbal descriptions. If new or modified curricular designs are to be produced, a greater utilization of the nonverbal and visual dimensions of mental creativity is required as the planners bring the elemental components together to form novel educational programs. Although we may assemble and manipulate the elemental parts to shape a complete learning system, contrasts and comparisons between such invented patterns are not clearly discerned without drawing upon the visual sense as well as the abstract and rational skills of reasoning. Without the aid of the visual representation there may in fact be no defensible reasons for choosing one system design rather than another. It has been the assumption throughout this monograph that the very complex sets of educational variables can be more effectively manipulated by exchanges of information using auxiliary pictorial and other nonverbal forms emphasizing structural interrelationships.

This point can be underscored by returning briefly to the re-examination of the distribution and core patterns for general education which share some common structural features. Four widely used variations on these formats for the general component in the total curriculum are shown in Figure 8-5. In many distribution and core requirements the general studies and specialized studies components are completely separate portions of the undergraduate educational experiences of students. Therefore, these are disjoint sets of elements with respect to the total curriculum as shown by diagrams A and B, providing only a breadth of disciplinary education for the students. However, within the isolated general studies component some institutions have fused selected requirements into multidisciplinary or unified forms stressing the integrative role of two or more disciplines in studying human behavior and the natural world. That condition is depicted specifically by diagram B. Efforts to overcome the disjoint separation of the general from the specialized areas of study have centered on two alternatives. First, pluri-disciplinary designs are used in which verbal, symbolic, and quantitative modes of human communication and thought serve as the common bridges between disciplinary areas for both the fields of specialization and in the required general studies. Diagram C demonstrates these primary supportive functions of composition, speech, mathematics and computing in building essential skills and giving practice in critical thinking by students. A second alternative is given in diagram D and involves the development of special interdisciplinary courses in the social sciences and humanities which focus upon current or historical issues facing individuals and cultures, issues having sufficient scope to embrace aspects of the student's major field as well as some areas encompassed in the required general studies. Often interdisciplinary courses of this type necessitate stipulated pre-requisite background learning by the students in both the general and the specialized components before undertaking such poblem-solution studies.

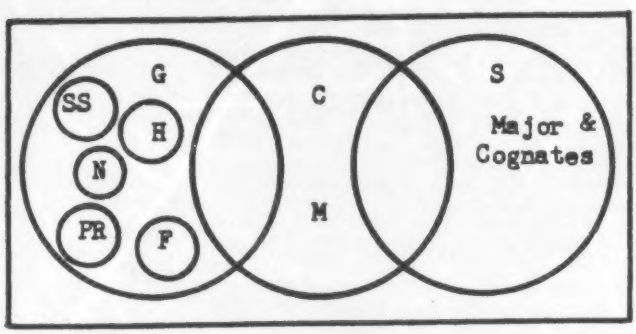
With the aid of the Venn diagrams in Figure 8-5 the distinctive forms used in distribution and core requirement patterns for general education are quickly seen and comparisons among selected designs can be elaborated. However, for more complex schemes for general education as a part of liberal learning, broader approaches to construction of the curricular models may be necessary. The metaproblem posed for designers of curricula is much like the challenge encountered in simulation techniques used to construct models of other real social or physical systems. For both areas, the very fundamental question which must be addressed often remains unresolved; that is, "how can the maximum amount of information about the forms and outcomes of the model be communicated most effectively to other persons without losing sight of essential relationships which have been established?". Ultimately our perceptions of those patterns and conclus-



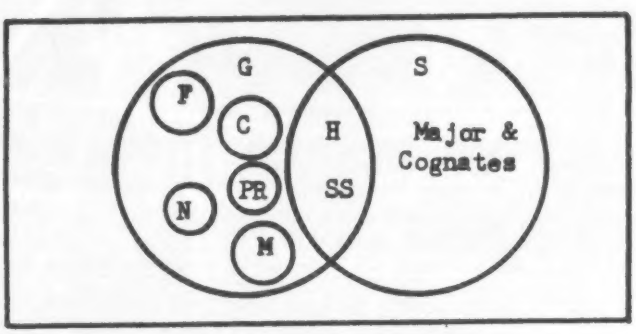
A. Disciplinary Distribution or Core Requirements



B. Multidisciplinary Core Requirements with Integrative Courses in Some Areas



C. Pluri-disciplinary Core or Distribution Requirements



D. Core Requirements with Interdisciplinary Courses

Code: G general studies
C communication & speech
PR philosophy & religion
SS social sciences
N natural sciences
M mathematics & computing
H humanities
F fine arts & music
S specialized studies

Figure 8-5. Some variations on the distribution and core requirements for general education

ions drawn from a given model will be qualitative rather than numerical so that a presentation of data items in tabular form usually conveys less information about the outcomes of the model than does some type of graph depicting trends in key variables. The hypergraphic problem of reduction of complex n-dimensional information to clear graphical forms of either two or three dimensions has neither a single nor simple solution for representations of curricula.

The dimensionality of the complex relationships between learning factors well exceeds our usual world of two dimensional sheets of paper or CRT screens used to construct graphic surfaces by computer. Our most likely choice for the less complex models is to make two-dimensional displays as x vs. y for the pairwise comparisons between dominant variables or to extend these binary plots to three dimensions by adding a variable having a common dependence on the first two. The latter is illustrated by the Berman diagrams (Figure 1-6) in which process elements in learning are related to both content and methodology in teaching. Another simple option for the two-dimensional graph is to plot two unrelated dependent variables in the y-direction if each of them has a common relationship to x; and the result will be two separate curves having one coordinate in common. Similarly, if two closely related and important variables have been identified, construction of a ratio scale between them will allow one to plot the relative proportion for that pair as a function of a third variable (i.e. a:b vs. x). Greater visual contrasts can be achieved as well as by incorporating different colors and hues into the x vs. y graph as is done by computer graphics. On the other hand, if the model requires a dimensionality greater than three, no visible graphic depiction of the trends among interrelated parameters can be made without losing some information; and the main problem for such a case is to minimize that information loss through innovative trial reductions to binary graphs or three dimensional surfaces. However, personal judgements about the significance of each variable are implied within any decisions to reduce the dimensionality of the system and its information to yield visual surfaces, lines or shapes.

A visual model changes qualitatively the ease with which we can describe our fundamental ideas about the curriculum by inserting a different and nonverbal perspective, one which can often reduce the verbal ambiguities of our supporting arguments for a particular set of goals and its derived program for learning. As an aid to systematic thought, the educational model permits us to not only examine the interconnections between its elemental parts but also to identify some possible variations within that completed design instead of stipulating a single unique assembly for the form of the total learning system. Such a visual model for the liberal arts curriculum should couple a more precise symbolic language with relevant mathematical constructs and nonverbal images if we are to transform our objectives into a design which will operate as a coherent educational system fostering changes in the intellectual and social behavior of students in a real and expansive world of learning.

The model for a liberal arts curriculum will guide those essential processes and conditions forming a learning environment in which the experiences of higher education lead toward a transformation of the self. In this way the model must touch upon the ethical assumptions made about liberal education since the fundamental learning operations are deliberately extended beyond the training of the mind and body toward reformed personal attitudes and behavior. In principle such a realignment of many components of the learning

system will redirect those values and mental attitudes as well as the learning skills toward specific long-term educational goals, thereby enabling the student to know and see wholly and to act responsibly in the world as it really is and as it might become.

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Appendix 1

A CASE STUDY

The analytical approach to the description of liberal arts curricula can be illustrated by a specific case study of the requirements for the B. A. degree from the College of Liberal Arts within a representative state university (R. S. U.). One reason for the choice of R. S. U. in preference to an exclusively undergraduate institution is the fact that regionally the greatest number of students electing liberal arts education obtain the B. A. or B. S. within the setting of the state universities. Even though the undergraduate curricula of the universities may be less innovative than those of some of the smaller liberal arts colleges, their quantitative impact upon the total spectrum of undergraduate higher education is quite important.

Program Data

From the 1979-80 catalog of R. S. U., we learn that nearly 45% of the 19,000 member student body are enrolled in the College of Liberal Arts and Sciences. The University claims that about 70% of those receiving degrees from the College continue on to graduate and professional schools. Although the student attrition rate is large, many students transfer from the College to other more specialized schools (i.e. Fine Arts, Engineering, Education, etc.) within R. S. U. before completing their undergraduate degree programs. The College offers majors in some thirty-four departments plus a number of area and interdisciplinary majors, as well as a broad major leading to the Bachelor of General Studies degree. All of the departmental major programs require 30 to 45 credit hours in a single discipline; and from 15 to 30 additional credit hours are usually specified in areas which are supportive to the disciplinary major. A minimum total of 124 credit hours is required for the B. A. degree.

In addition to the various departmental majors, the College of Liberal Arts is the center for all of the undergraduate general studies courses given by the University and these service the needs of the specialized schools as well as the College itself. The stated requirements in general education apply to all students planning for the B. A. or B. S. degrees from the College of Liberal Arts.

1. Objectives of the General Requirements. To provide a breadth of knowledge without superficiality and a depth of knowledge without over specialization. The range of the requirements includes both theory and practice within the humanities, social sciences, and natural sciences.

2. Specific Requirements (or Common Core Requirements).

English composition and literature	9 cr. hr.
Speech fundamentals	2
Foreign language - one year proficiency (possible by examination)	10
Mathematics - algebra proficiency and two courses in mathematics and/or logic	6-8

Laboratory science - one principal course	4-5
Western civilization - readings from major sources	6
Subtotal	37-40

3. Distribution Requirements - with options which may include the laboratory science from above. Minimum of three departmental courses from each of these areas:

   (a) Humanities - chosen from history, languages, drama, and philosophy.
   (b) Mathematics and Natural Sciences - selected from mathematics, chemistry, geology, biology, meteorology, and physics.
   (c) Social Sciences - includes the areas of anthropology, geography, economics, psychology, political science, and sociology.

   Subtotal 17-20

Total for General Education: 54 - 60 cr. hr.

A Model

From the statement of objectives as well as the specific general education requirements, it is clear that the curriculum of the College is designed to force the student to interact with a number of selected disciplines. If one uses the Dressel classifications (Chapter II), the program is one of examined diversity or essentially the cumulative distribution plan. By tracing course numbers and the course descriptions in the catalog, we find that the components of the common core are serving the needs of both the major student in the discipline and the general liberal arts student, without differentiation. The only exception to this pattern is the course, Western Civilization, which follows a "Great Books" plan and is a completely separate entity. The common core as well as the distributive requirements are drawn largely from the lower level departmental courses. Aside from English composition and literature, the sequence for meeting the requirements is optional with the student or the major department.

A linear vector model is suitable for the description of the R. S. U. program in liberal arts and the parallel alignment shown in Figure A-1 is the appropriate form. The curricular forces in the general requirements act in the same direction as those in the disciplinary specialities, since the distinction is one of distribution rather than content.

Summary

One outcome is that the student in the College of Liberal Arts and Sciences can have a breadth of educational experiences in the three areas, humanities, natural sciences, and social sciences. However, since that student is likely to major in a department within one of those areas (if following the B. A. program), the real extension is restricted to only two areas of the distribution requirements. The choice of disciplines included in the general requirements is somewhat arbitrary since the fine arts, visual arts, business, and applied sciences are completely ignored. On the other hand, the breadth dimension for the curriculum in the College of Liberal Arts is at least twice as large as that in the more specialized schools in the University.

Any cross-disciplinary comparisons which may arise during the time spent

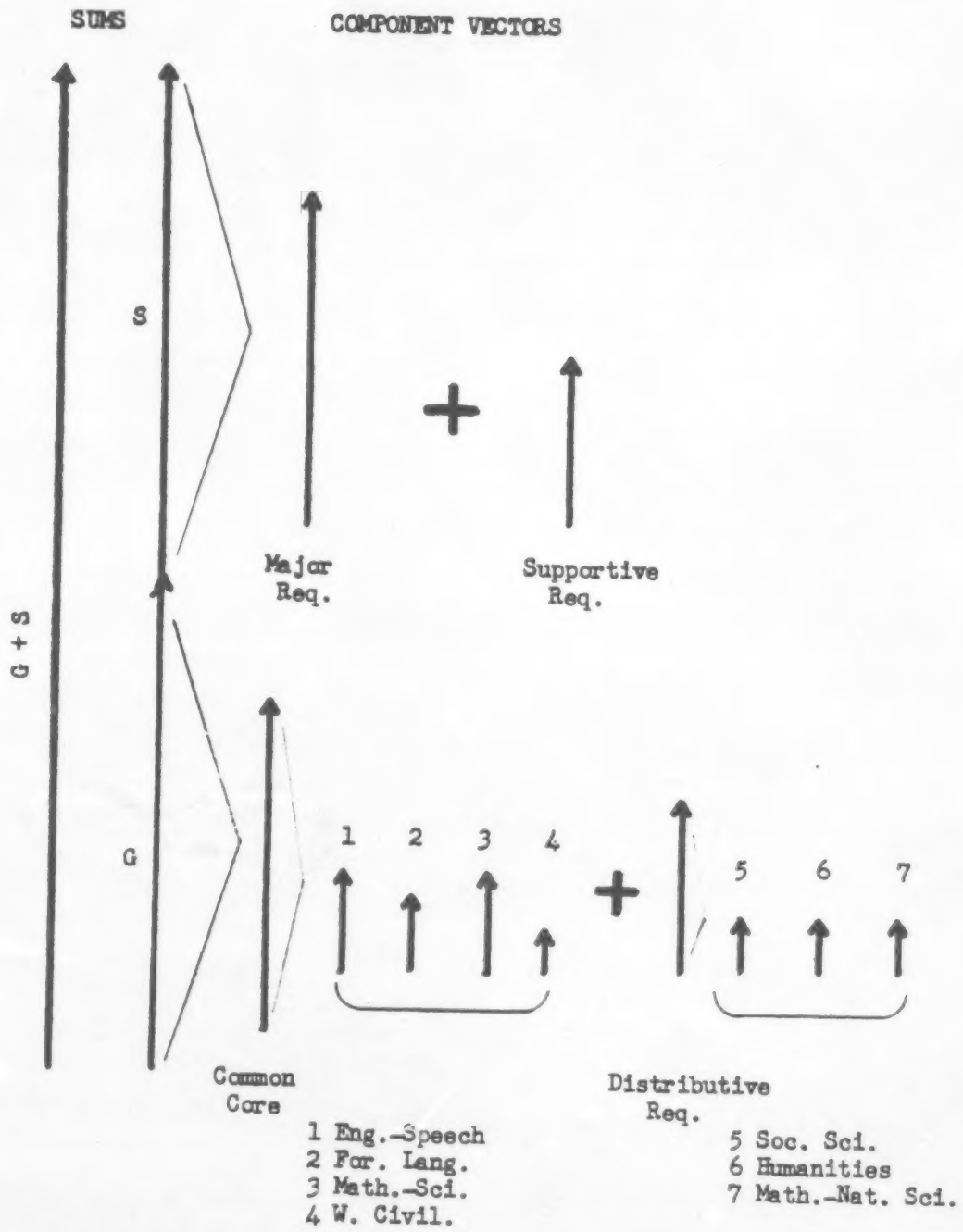

Figure A-1. Vector model for the College of Liberal Arts curriculum.

in meeting the general requirements will be largely random events originating from either the creativity of the student or the unusual teacher whose interests extend beyond the discipline. For this condition, the predominant character of the curriculum suggests a model no more complex than that of simple linear vectors in the required parallel orientation. In this case the vector sum (or resultant of G and S) retains an overall S-directional property of its component vectors.

Appendix 2

ALTERNATE METHODS FOR PATTERN RECOGNITION

One objective in pattern recognition is to find suitable boundaries (or decision surfaces) which discriminate between data points in different regions of the coordinate space, since points in the same class will occupy the same region in that space. In Chapter V the simplest approach to this goal of classification, namely the binary classifier, was outlined; however, there are many circumstances for which that method is inadequate even though extensive pre-processing operations may have been performed.

For binary grouping problems, the discriminant function applied to the two classes is termed a linear classifier because the dichotomizing function is linear in two-dimensional space or planar in three-dimensional space. If a linear discriminant function cannot be found, a polynomial decision function can be used with the training set. The general statement of the polynomial function in the variable x is given in equation 1,

$$f(x) = a_o + a_1x + a_2x^2 + \ldots + a_nx^n \qquad (1)$$

and specific polynomial functions are shown in equations 2, 3, and 4.

1st degree(linear): $$f(x) = a_o + a_1x \qquad (2)$$

2nd degree(quadratic): $$f(x) = a_o + a_1x + a_2x^2 \qquad (3)$$

3rd degree(cubic): $$f(x) = a_o + a_1x + a_2x^2 + a_3x^3 \qquad (4)$$

The application of the quadratic as the discriminant function in a decision surface results in a spherical, ellipsoidal, parabolic, or hyperbolic geometry for that surface; and the coefficients for the two-dimensional case (equation 5) must be computed from the training set for each anticipated pattern in the test set.

Quadratic: $$f(x,y) = c_o + a_1x + b_1y + a_2x^2 + cxy + b_2y^2 \qquad (5)$$

With higher degree polynomials the number of required computations is drastically increased.

In addition to problems arising from linearly nonseparable clusters of data points, other complicating factors can occur. The points may represent the intermingling of two or more unequal populations of data items; or stray and erratic points may be present in the partially separated clusters, as in Figure A-2. Also, partitioning boundaries may be difficult to identify because of differing internal structures within the clusters of points (i.e. elongated clusters with parallel or perpendicular axes). It is often possible to treat these problems in an approximate manner by means of more than one linear decision boundary (or hyperplane).

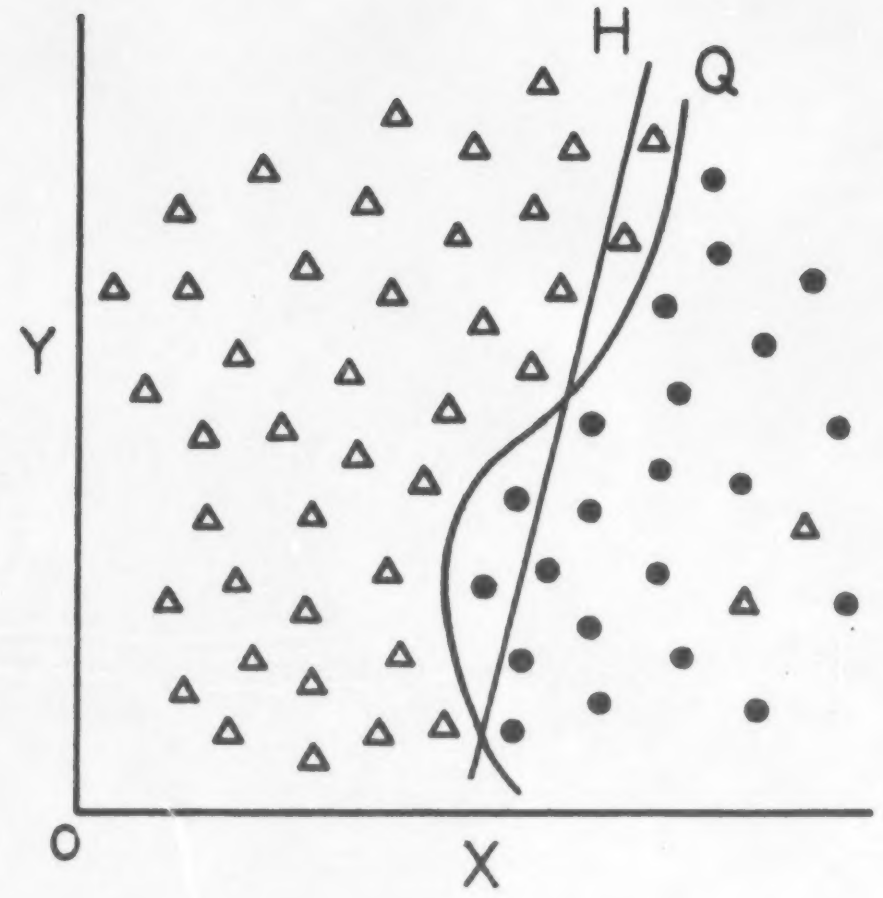

Figure A-2. Unequal and linearly nonseparable clusters with strays. Curve H is a hypothetical linear surface, and Q is the polynomial function.

The systematic elimination of less useful cluster features can be accomplished by learning machine techniques in which the dimensionality of the system is reduced and only the most relevant features identified. Within this context methods utilizing convergence properties and statistical estimates are appropriate.

An alternative procedure applicable to nonlinearly separable categories and having a statistical basis is the K-nearest neighbor (KNN) classification rule. According to this method, an unknown pattern is classified upon a form of "majority vote" of its nearest neighbors in n-dimensional space; and that decision is derived from the computed distances(D) between the given point and all other points in pattern space. For a pair of points, i and j,

$$D_{ij} = \left[\sum_{k=1}^{n} (X_{ik} - X_{jk})^2 \right]^{1/2} . \qquad (6)$$

In order to minimize the probability of making an error in classifying pattern components a statistical risk function(R) is introduced which is related to the Bayes risk(R*) and the K-value. For additional information on this procedure for classification, the reader may consult:

H. C. Andrews, Introduction to Mathematical Techniques in Pattern Recognition, Wiley-Interscience, New York, N. Y., 1972.

It should be clear from Figure A-2 that the number of dimensions required to describe either a linear or polynomial discriminant function as a mathematical equation will be the same as the number of dimensions used in plotting the data points. Likewise, it is the set of weighting coefficients ($W = w_1, w_2, w_3, \ldots$) which ultimately define the location of the decision line for separable data items. As noted in Chapter V, the weighting coefficients are themselves vectors which are directed perpendicular to the decision line or plane. This concept is shown in Figure A-3. The best or optimum weight vector (W) will be the one capable of classifying all of the data items into separate categories without error.

The weight vector (W) may be trained against a set of patterns whose classes are known so that both its algebraic sign and weight are involved in feature selection. Thus, W^+ and W^- for the components of the pattern determine which components are retained; and those having opposite signs are discarded. In effect some points in the set become eliminated in this process, thereby reducing the number of distinctive features used in the binary classification scheme. However, if plural features are being eliminated, there is the risk that some patterns may become identical with the result that the weight-sign discriminant function is misleading as a classifier.

Another procedure for identifying the near optimum weight vector set for seemingly non-separable data is the "simplex method" of pattern recognition. From a geometric point of view, a simplex figure is a polyhedron having (d + 1) vertices for the d-dimensional space used to depict the data. That is, if the data are plotted as y vs. x (two dimensions), the simplex used to establish the weight vectors will be triangular; and the trial simplex is moved sequentially through weight vector space in response to albegraic per-

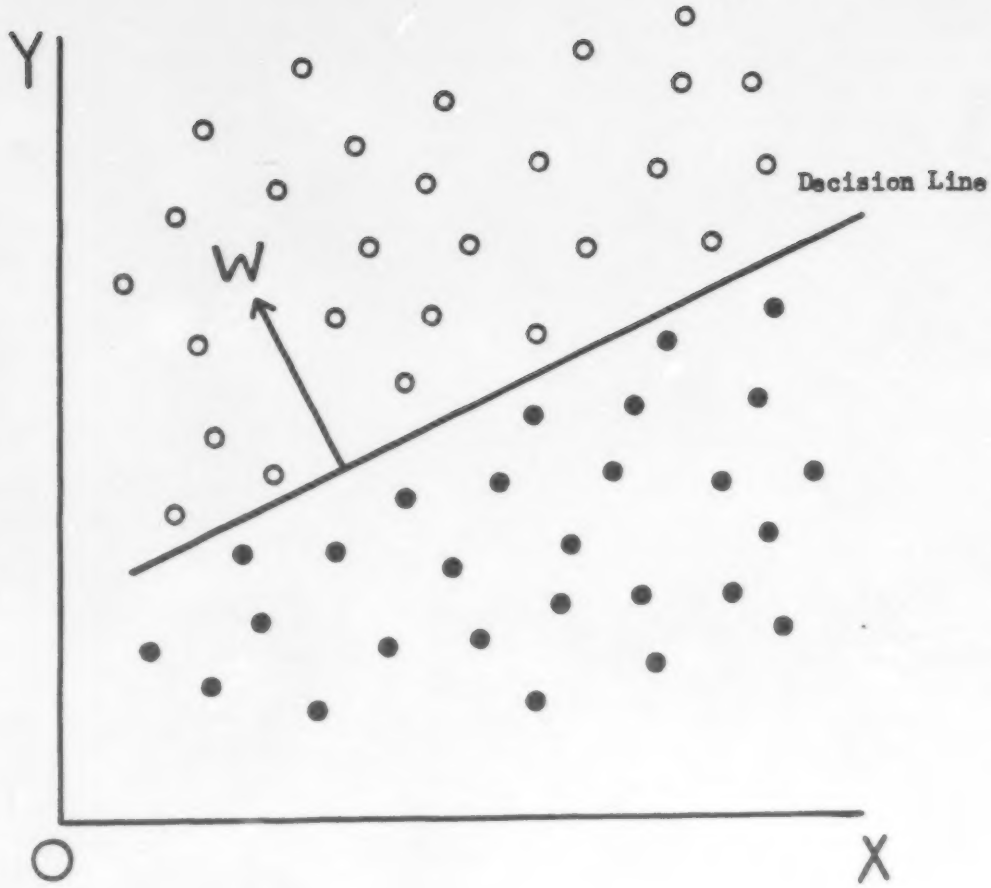

Figure A-3. Weighting coefficients as vectors

ceptron criteria. The predictive capability of the simplex and K-nearest neighbor techniques appears to be comparable. Details of the simplex method are given in the following sources:

G. S. G. Beveridge and R. S. Schechter, Optimization: Theory and Practice, McGraw-Hill Book Co., New York, N. Y., 1970.

R. O. Duda and P. E. Hart, Pattern Recognition and Scene Analysis, Wiley-Interscience, New York, N. Y., 1973.

Appendix 3

SYMBOLISM FOR FLOW CHARTS

The flow chart is a graphic structure depicting the sequences in problem-solving and includes the specification of information entries, operations, decisions, and anticipated outcomes. In terms of its general pattern the flow chart utilizes an input-output organization to describe a given process. It indicates in an outline form the various steps in data or information movement along with any transformations or manipulations involving that information. Connecting lines and arrows show the direction of movement through the chart; and these identify the essential order within the overall process, the joining of a branching or auxiliary segment, and even intersections without connections. The connecting lines are called flowlines and the net direction in the process is represented by a vertical progression between input and outcome.

There are several different systems of notation used for drawing flow charts; however, the designs recommended by the American National Standards Institute (ANSI) provide a suitable base for adaptations to educational processes.[a] Although developed primarily for the analysis of data-information problems in business and industry, the ANSI symbols and charting conventions can be simplified and modified for non-computerized descriptions of problems in the area of education. A few of the more useful symbols for emphasizing process elements and/or operations (i.e. the "how-dimension") are listed in Figure A-4.

As an assembly of symbolized operations and movements, a given flow chart is intended to simulate the basic processes which determine the behavior and outcomes of that system. However, it must be recognized that such a simulation is an artificial scheme imitating some of the behavior of the real system. It is most helpful in keeping track of the various sources of inputs into the system and the movement of information items having some relationship to its operations. The flow charts used herein to describe educational processes are admittedly incomplete in that not all decision points have been fully specified nor have all of the possible options in branching networks been stated. When applied in this simplified way, the flow chart simulation retains a visual compactness needed for concise descriptions of educational processes (i.e. learning modes) without the full detailing of all steps required for programming a numerical analysis of parameters.

The goal for many flow chart applications is to describe very accurately all operational steps so that the detailed sequence can be transformed into a computer program. No such stipulation of the purist has been advocated in this monograph, for flow charts need not be so restricted in order to describe educational processes like teaching in a manner depicting the important fundamental steps with increased clarity.

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[a] Ned Chapin, "Flowcharting with the ANSI Standard: A Tutorial", Computing Surveys, vol. 2, no. 2, 1970, p. 119-143.

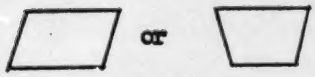
VERBAL DESCRIPTION	SYMBOL
A terminal point	
Input or output	
Preparatory operation	
Auxiliary operation	
Major process or operation	
Merge	
Extract	
Sorting	
Decision point	
Multiple decisions (exceeding three)	

Figure A-4. Identification of symbols in flow charts

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